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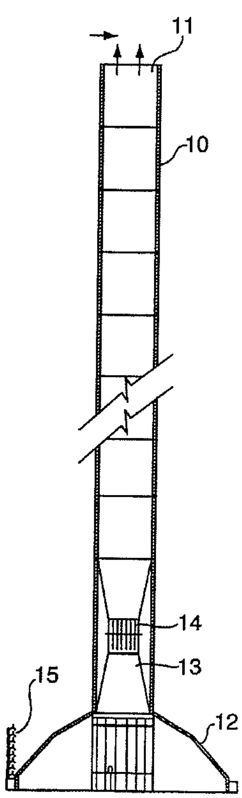
(54) Title: SOLAR CHIMNEY WIND TURBINE



(57) Abstract: A solar energy powerplant comprises at least one vertical tower with an open top mounted on a base structure. Each tower (10) has a height of at least 100 metres with a plurality of outwardly projecting heating chambers (12) mounted externally around the lower end of the vertical tower. Each heating chamber is a generally hollow chamber with walls formed of thin metal sheeting for absorbing solar energy, a closeable opening in a lower region of the chamber for introducing ambient air into the chamber and a closeable opening in an upper region of the chamber for releasing heated air accumulated in the chamber into the tower. A constricted zone, e.g. Venturi chamber, within the tower above the heated air inlet openings is adapted to increase the velocity of the heated air moving up the tower, and a wind powered turbine (14) is mounted within the constricted zone and adapted to drive an electrical generating unit. The height of each tower and the number and size of the heating chambers connected thereto are sufficient to provide a substantially continuous updraft in the tower for driving the turbine.

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SOLAR CHIMNEY WIND TURBINE

Technical Field

This invention relates to a system for producing electrical energy, particularly with the use of solar heat as the prime energy source.

Background Art

The patent literature is replete with systems utilizing wind, waves, and solar heat as energy sources for generating electrical power. The main sources of electrical power in the world today are hydroelectric systems and fossil fuel powered generating systems. The next most significant source of electrical power is nuclear powered generators.

As far as hydroelectric power is concerned, the power generators must be reasonably close to their ultimate market and the heavily populated and industrialized sections of the world are fast using up all available new sources of hydropower. The systems powered by fossil fuels such as coal, gas and oil have the problem that these fuels are now becoming in short supply and also are becoming extremely expensive. Also, fossil fuels are environmentally objectionable, since these contribute to global warming and also contaminate the atmosphere by leaving poisonous residues not only in the air, but also often in many effluents. The nuclear systems are not only very expensive in terms of construction costs but they also have the problem of requiring extensive safety systems to protect against the radiation in the plant itself. Moreover, there is also the major problem of safely disposing of the highly dangerous wastes.

Because of these problems with the traditional systems, there has been a greatly increased interest in solar energy as a major energy source. Various systems have been proposed involving the use of solar energy for generating electrical power and some such systems

have recently been developed for space vehicles; see, for instance, Canadian Patent No. 718,175, issued September 21, 1965. That system uses a solar energy absorber for heating a liquid which vaporizes to drive a turbine which in turn drives a generator. Such a system with its vaporizing and condensing systems is obviously practical only for very small systems such as would be used in space crafts.

There are many patents in existence which describe the use of wind power for driving electrical generators and one form of wind turbine generator is that described in U.S. Patent No. 3,720,840 issued March 14, 1973. In Goodman, U.S. Patent No. 3,048,066, a vertical stack arrangement is described having a series of fans driven by solar created thermal currents, with the fans being capable of driving electric generators.

The failure of ground level solar energy collectors in the past has been related to an inadequate collection area. Thus, it is known that for a sunny region such as Texas, an average heat absorption of an optimally tilted collector is about 0.45 kw/m^2 as a year round average sunny, daylight hours. On this basis it has been estimated that a collector area of 37 square miles would be required for a 1000 mw powerplant.

Of course, it is highly desirable to have these plants close to major population areas and in these areas land is at a premium. One design of solar powerplant capable of greatly decreasing the land area requirements for a given amount of power production is that described in Drucker, U.S. Patent No. 3,979,597, issued September 7, 1976. Further improvements to that solar powerplant are described in Drucker, U.S. Patent No. 5,694,774 and WO 99/47809.

In recent years there has been a growing interest in the solar chimneys. It consists of a very tall chimney, e.g. as high as 1000 metres with a hot air

collector at the base. Turbines are mounted within the chimney in a lower region. A chimney of this type that is very tall relative to its diameter produces the highest upward velocities, with rising warm air within the chimney achieving speeds of 110 kph or more. Systems of this type have been constructed, but have encountered difficulties with both efficiency and durability.

A wind or water operated powerplant is described in Cohen, U.S. Patent 4,079,264, which includes a Venturi passage. A rotary power device, e.g. a turbine, is mounted within the throat of the Venturi.

It is an object of the present invention to provide an improved form of solar energy powerplant having as a principal component one or more tall vertical towers.

It is a further object of the invention to advantageously use the tall vertical tower powerplant in combination with a Venturi passage.

Disclosure of the Invention

In accordance with the present invention there is provided a solar energy powerplant for producing electrical energy having as a principal component one or more tall vertical towers. Each tower is mounted on a base structure and is open at the top to permit an updraft. Wind powered turbines are mounted in the tower such that chimney updrafts in the tower drives the turbines. The turbines in turn drive electrical generators.

A large heat input is required in order to generate the heat necessary for the updrafts to drive the turbines. In accordance with this invention, a plurality of radially spaced, outwardly projecting heating chambers are mounted externally around the base of each tower. Each of these heating chambers is a generally hollow chamber with walls formed of thin metal sheeting for absorbing solar energy. A closeable

inlet opening is provided for introducing ambient air into the chamber and a closeable outlet opening is provided for releasing heated air accumulated in the chamber into the tower.

Typically at least 20 heating chambers surround a tower and the inlet and outlet closures in each of these chambers may be adjustable whereby the closures remain closed while ambient air trapped within the chambers is heated to a predetermined temperature, at which time both closures open to transfer heated air to the tower and replace it with ambient air. In this manner the heating chambers can be sequentially opened and closed individually or in groups whereby a continuous strong updraft is maintained.

A constricted zone is provided within the tower directly above the heated air inlets, this comprising a Venturi chamber adapted to increase the velocity of the heated air moving up the tower. A turbine is mounted within the throat of the Venturi chamber at a point of maximum air velocity. The Venturi chamber serves to at least triple the speed of the rising air stream driving the turbine. The height of each tower and the number and size of the heating chambers connected thereto are sufficient to provide a substantially continuous updraft in the tower for driving the turbine.

It has been found that for maximum efficiency, it is important to maintain a low moisture level in the updraft air. Otherwise, condensation takes place within the tower, which not only interferes with the updraft but also causes corrosion. Accordingly, where required, the inlet air is passed through a dehumidifier prior to entering the tower. The air should enter the tower at a moisture level of less than about 10% and preferably less than about 5%. Dehumidifiers may conveniently be located in upper regions of the heating chambers and/or within the Venturi chamber below the turbine.

Each tower is preferably circular in cross-section and each Venturi chamber is preferably in the form of an inwardly tapered frusto-conical inlet portion, a central throat portion of square or rectangular cross-section and an outwardly tapered frusto-conical outlet portion. The wind powered turbine is mounted within the central throat portion on either a horizontal or vertical axis. The turbine drives a generator for generating electrical energy.

While the powerplant of this invention is intended to be powered primarily by solar energy, the heat requirements within the heating chambers may be supplemented by additional heaters. For instance, in situations where a powerplant according to the invention is intended to provide electrical power 24 hours a day, sunlight is the power source during day light hours and gas burners may be provided in the heating chambers for heating during hours without sunlight. This remains an efficient system since only a small increase in temperature of the ambient air is required to create the necessary updraft in the tall towers. Typically a temperature differential of 7-8°C is sufficient to provide the necessary updraft.

In desert regions, another source of night heat is to provide a layer of asphalt in the bottom of each heating chamber. This asphalt absorbs large quantities of heat during the very hot desert day and slowly releases the heat to the air passing through the chamber at night.

It is also advantageous according to this invention to locate the towers in regions having strong prevailing winds. Thus, the greater is the speed of the wind blowing across the top of the towers the greater is the air updraft within the towers.

According to a further feature of this invention, the surfaces on the tower exposed to the rays of the sun provide excellent locations for photovoltaic cells.

The photovoltaic cells are used for direct production of additional electricity during sunlight hours.

Best Modes for Carrying out the Invention

The tower is tall relative to its diameter, e.g. a ratio of height:diameter of at least 10:1, since this produces the highest upward air velocities. A commercial tower may have a height of 400 metres or more and a diameter of as much as 30 metres. Rising warm air within such a tower can achieve speeds of up to 110 kph. In one preferred embodiment, a tower 30 metres in diameter has a Venturi chamber with a throat portion having an area of about 144 m^2. Typically, a tower comprises a concrete lower portion extending upwardly less than about 25% of the total height of the tower. For the above commercial tower, the concrete base portion has a height of about 30 metres. Above this concrete base portion is mounted an insulated steel tower.

The heating chambers are also large and an individual chamber may have a volume of as much as 4000 m^3. This means that a tower with 20 such heating chambers has a total air heating volume of 80000 m^3.

It is preferred to operate the heating chambers in pairs. In this way, with the above arrangement 2 x 4000 m^3 = 8000 m^3 of heated air is sequentially released to the Venturi chamber every 2 minutes. The temperature differential is typically about 7°C. It is also possible to feed additional outside air directly into the Venturi chamber thereby increasing the air flow by as much as 40%. When this is done, the temperature differential for the air passing through the Venturi chamber is about 5°C.

In night time operation, the temperature differential is about 18°C without additional air feeding directly into the tower, while with an additional 40% air being fed in, the temperature differential is about 12°C.

The powerplant is provided with automatic controls which regulate the air flow travelling up the tower. This is conveniently done by measuring the turbine speed within the tower and utilizing this to control dampers on air inlets to the solar heating chambers and the inlets from the heating chambers to the tower. For instance, during periods of peak solar radiation, there is sufficient solar energy to provide a maximum updraft in the tower. On the other hand, during periods of minimum solar radiation, the auxiliary heaters in the heating chambers are used. In this way, a relatively constant upward air flow through the tower is maintained.

It is also necessary to monitor the moisture content of the air within the tower and make the necessary adjustments to maintain the moisture level below a maximum permitted amount which is less than 10%.

Brief Description of the Drawings

The invention is further illustrated by the attached drawings, in which:

Fig. 1 is a schematic elevation view of a tower according to the invention;

Fig. 2 is an elation view of a constructed zone;

Fig. 3 is a partial top plan view showing an arrangement of heating chambers;

Fig. 4 is a perspective view of a heating chamber base;

Fig. 5 is a perspective view of a heating chamber; and

Fig. 6 is a sectional view of the heating chamber of Fig. 4 and the tower.

The general appearance of the powerplant of this invention can be seen from Figure 1. Thus, it comprises a tall slender tower 10 having an open top 11 and surrounded at the bottom by a series of radially projecting heating chambers 12. Directly above the

heating chambers 12 within the tower 10 is a Venturi chamber 13 containing a turbine 14. Moveable reflectors 15 may be used to concentrate the rays of the sun onto the heating chambers 12.

The design of a preferred form of heating chamber can be seen from Figures 3 to 6.

Figure 3 is a partial top plan view showing how the heating chambers 12 are arranged relative to the tower 10. As seen in Figure 5, each heating chamber 12 is preferably formed of light gauge, black painted sheet metal and glass panels. Thus, each chamber includes sheet metal sidewall panels 24, inner end wall 25, outer end wall 27 and intermediate panels 29 and 30 and a concrete base 26. The outer end wall 27 includes a glass panel 32 for auxiliary radiant input and also includes a closeable ambient air inlet 33. A sloping wall is provided between outer wall 27 and intermediate panel 29. This sloping wall includes glass panels 28 to again permit the penetration of sun rays. Panels 29 and 30 are black coloured to absorb heat and a further sloping face is provided between the top of panel 30 and the top of inner wall 25. This sloping panel also includes further glass panels 31 to permit entry of sun rays. An outlet opening 34 is located at the top of inner wall 25 and this comprises a closeable opening for feeding heated air from the heating chamber 12 into the tower 10. Auxiliary heaters 35 may also be provided for heating the chambers where there is insufficient sun. These heaters 35 are preferably burners fueled by gas.

As further seen from Figure 5, the walls of each heating chamber 12 provide a wedge-shaped gap 36 between the heating chambers and this serves to provide more wall panel surface area for solar heating.

The air inlet 33 to each chamber 12 and the air outlet 34 are controlled by adjustable closures (not shown), preferably operated by electric motors. These

adjustable closures are of known type and may be selectively adjusted to any point between fully open and fully closed in response to computer signals.

Further air inlets 22 are located at the base of the Venturi chamber 13 and these connect directly to the outside. Flow through these inlets is controlled by adjustable closures (not shown) and preferably operated by electric motors. Depending upon atmospheric conditions, these inlets 22 can be opened to bleed as much as an additional 40% air into the stream of heated air emerging from the heating chambers.

A preferred form of base 26 for a heating chamber is shown in Figure 4. It includes lower sidewalls 42 on base 26 with the volume within the walls 42 being filled with asphalt 43. This is particularly advantageous in desert regions where ambient temperatures may range from a high of 45°C or more to night temperatures as low as 8-12°C. During the day the asphalt absorbs heat to the point of being liquified. During the night this very hot asphalt gradually cools, giving up its heat to the air passing through the heating chamber.

Figure 6 further shows the arrangement of the heating chambers 12 relative to the base of the tower 10. The bottom of the tower 10 is preferably supported on a heavy concrete foundation 37 and the walls of the tower up to the Venturi chamber 20 are preferably formed of reinforced concrete. The remainder of the tower is formed of metal, e.g. corrugated galvanized steel. Figure 6 more clearly shows the heated air outlets 34 from the heating chamber 12 into the tower 10 beneath the Venturi chamber 20.

Greater details of the Venturi chamber can be seen in Figure 2. Thus, it includes tapered frusto-conical portions 20 merging with a square throat portion 21 within which is mounted a turbine 14 on a

horizontal shaft 16. This powers an electric generator (not shown). Additional air may be fed into the tower through auxiliary air inlets 22. An elevator shaft 23 is provided for servicing the turbine 14.

A dehumidifier 40 is mounted in an upper region of each heating chamber 12 as shown in Figure 5. A further dehumidifier is also positioned within the inlet side of the Venturi chamber 13 as shown in Figure 2.

For optimum operating efficiency, each powerplant tower is controlled by a computer system. The following information is monitored and fed back to a computer.

i. Temperature and moisture content of air entering each heating chamber;
ii. Temperature and moisture content of air exiting each heating chamber and into tower;
iii. Air flow through each heating chamber;
iv. Air temperature inside and outside tower at about 8 metre intervals of the height of the tower;
v. Air speed inside the tower at about 8 metre intervals;
vi. Turbine speed (rpm) - about every 2 minutes;
vii. Air speed of air exiting top of tower (about every 2 minutes);
viii. Atmospheric wind velocity at top of tower; and
ix. Quantity of electricity being generated.

Based on this information, the computer is programmed to open and close the air inlet and outlet for each heating chamber, control the moisture content of the air passing up the tower, etc.

Claims:

1. A solar energy powerplant comprising at least one vertical tower with an open top mounted on a base structure,

each said tower having a height of at least 100 metres with a plurality of outwardly projecting heating chambers mounted externally around the lower end of the vertical tower, each said heating chamber being a generally hollow chamber with walls formed of thin metal sheeting for absorbing solar energy, a closeable opening in a lower region of each said chamber for introducing ambient air into the chamber and a closeable opening in an upper region of each said chamber for releasing heated air accumulated in the chamber into the tower, a constricted zone within the tower above the heated air inlet openings adapted to increase the velocity of the heated air moving up the tower, and a wind powered turbine mounted within said constricted zone and adapted to drive an electrical generating unit, and

the height of each tower and the number and size of the heating chambers connected thereto being sufficient to provide a substantially continuous updraft in the tower for driving the turbine.

2. A solar energy powerplant according to claim 1 wherein the tower is circular in cross-section.

3. A solar energy powerplant according to claim 2 wherein the tower includes a lower concrete portion adjacent the heating chambers and an upper insulated sheet metal portion.

4. A solar energy powerplant according to claim 1, 2 or 3 which includes mobile reflectors for directing sunlight onto the heating chambers.

5. A solar energy powerplant according to any one of claims 1-4 which includes auxiliary gas-fueled burners within the heating chambers.

6. A solar energy powerplant according to claim 2 wherein the constricted zone comprises a Venturi chamber having an inwardly tapered frusto-conical inlet portion, a central portion of square or rectangular cross-section and an outwardly tapered frusto-conical outlet portion.

7. A solar energy powerplant according to claim 6 wherein the wind powered turbine is mounted on a horizontal axis within the central portion of the Venturi chamber.

8. A solar energy powerplant according to any one of claims 1-7 which includes a dehumidifier for removing moisture from the ambient air entering the Venturi chamber.

9. A solar energy powerplant according to claim 8 wherein the dehumidifier is adapted to reduce the moisture of the air to less than 10%.

10. A solar energy powerplant according to claim 9 wherein dehumidifiers are located in an upper region of each heating chamber below the heated air outlet.

11. A solar energy powerplant according to claim 9 or 10 which also includes a dehumidifier located within the inlet portion of the Venturi chamber.

12. A solar energy powerplant according to any one of claims 1-11 which includes additional closeable air inlets for feeding outside air directly into tower below the Venturi chamber.

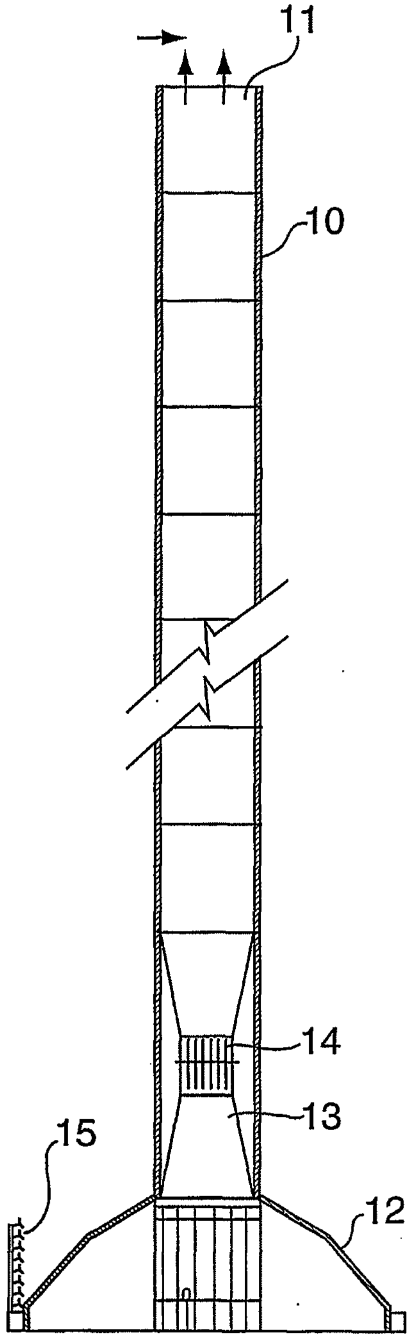

FIG. 1

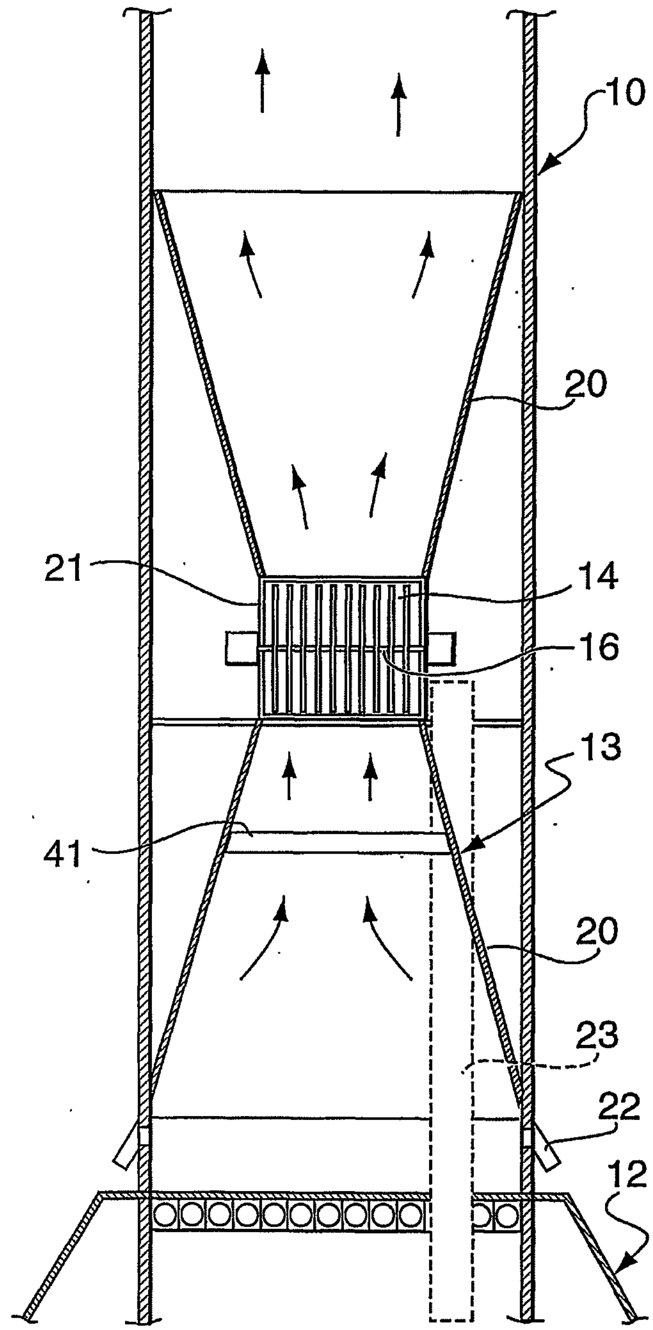

FIG. 2

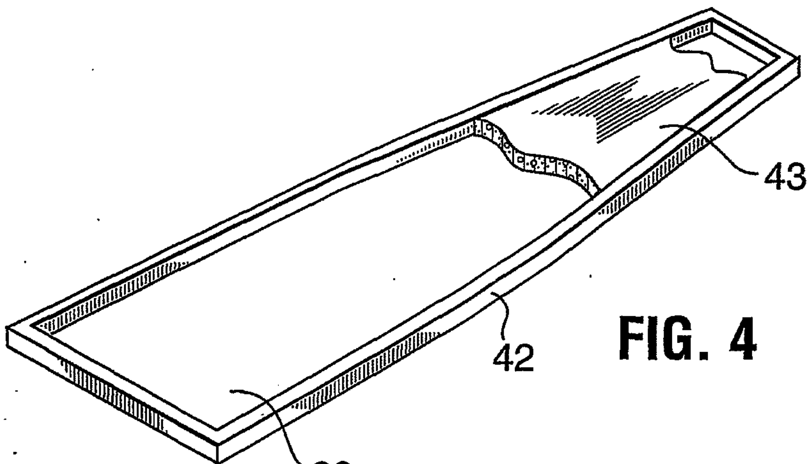

FIG. 4

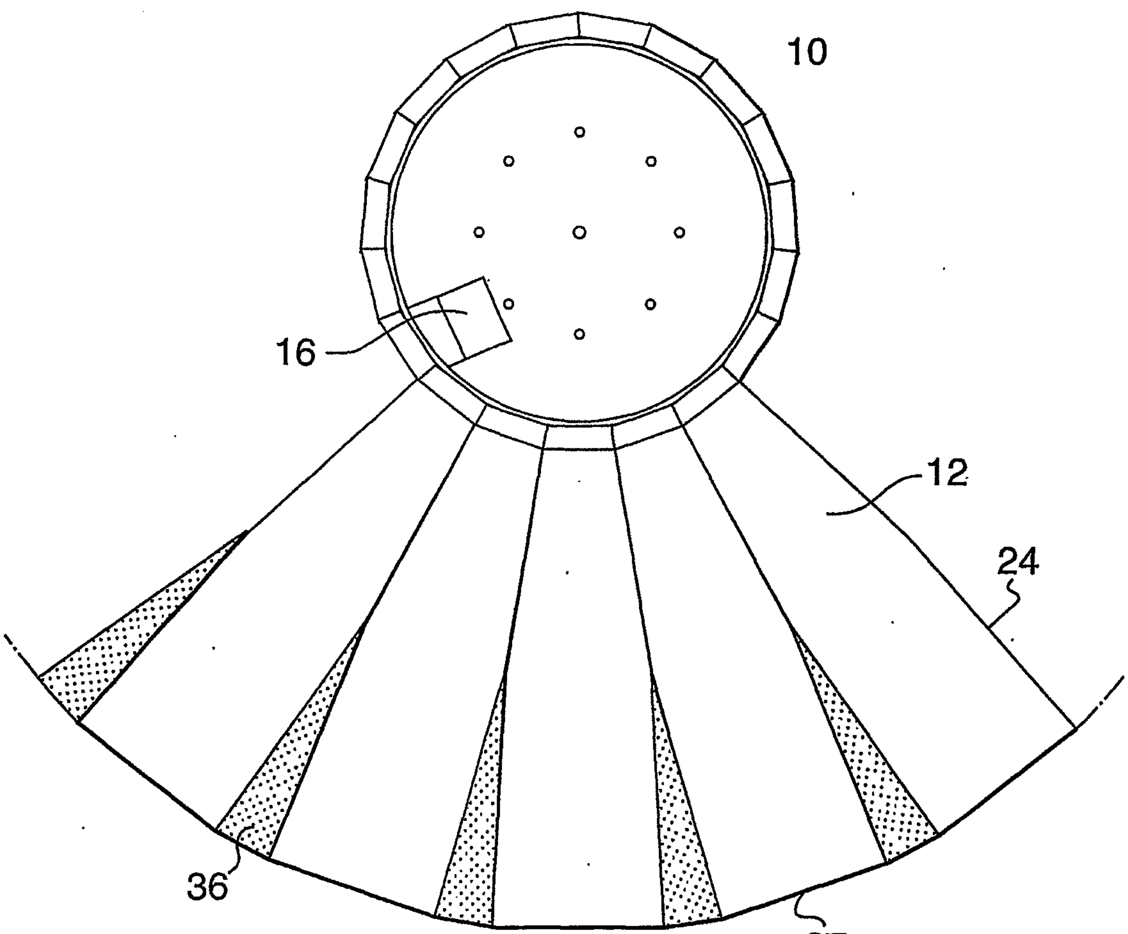

FIG. 3

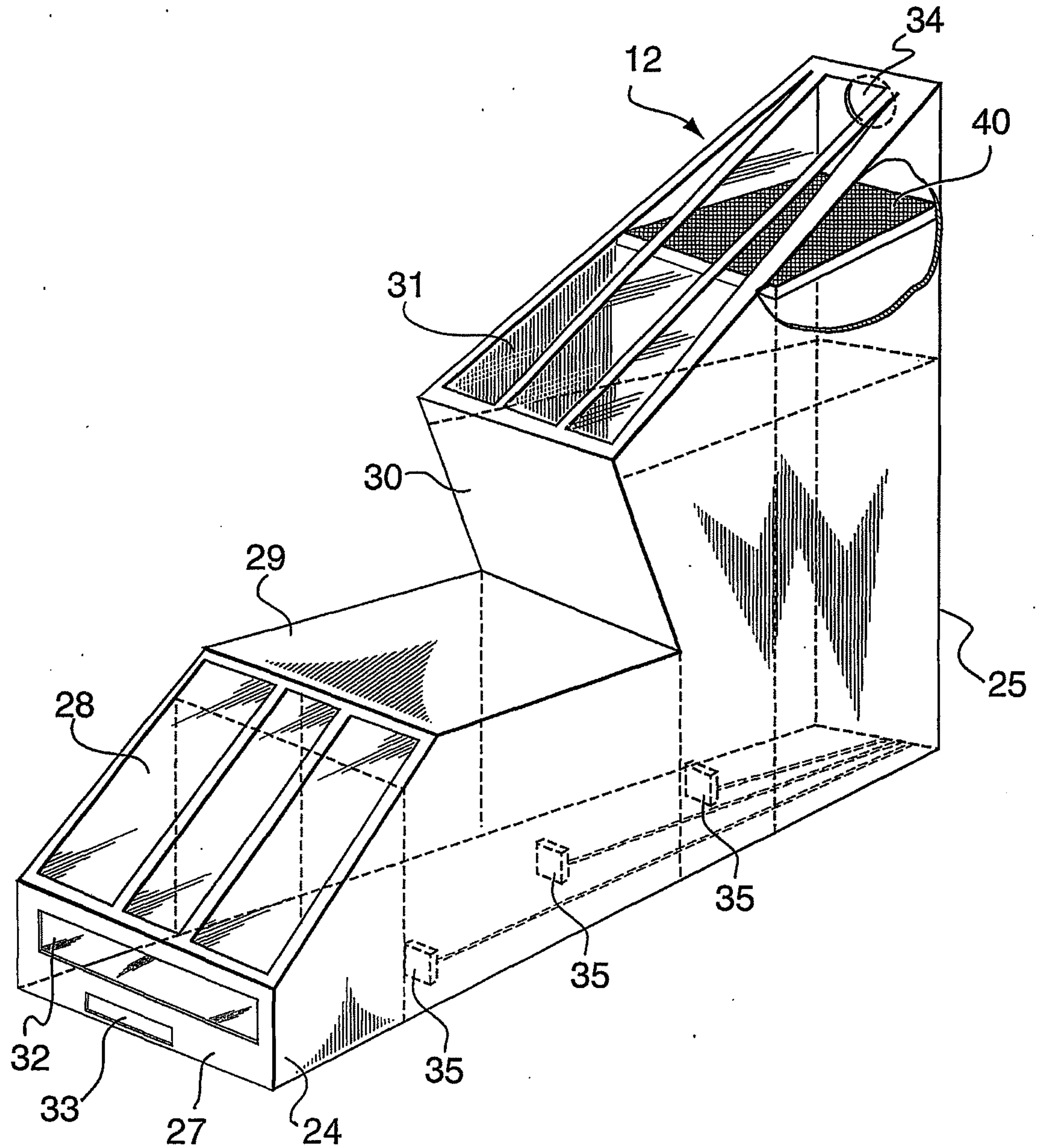

FIG. 5

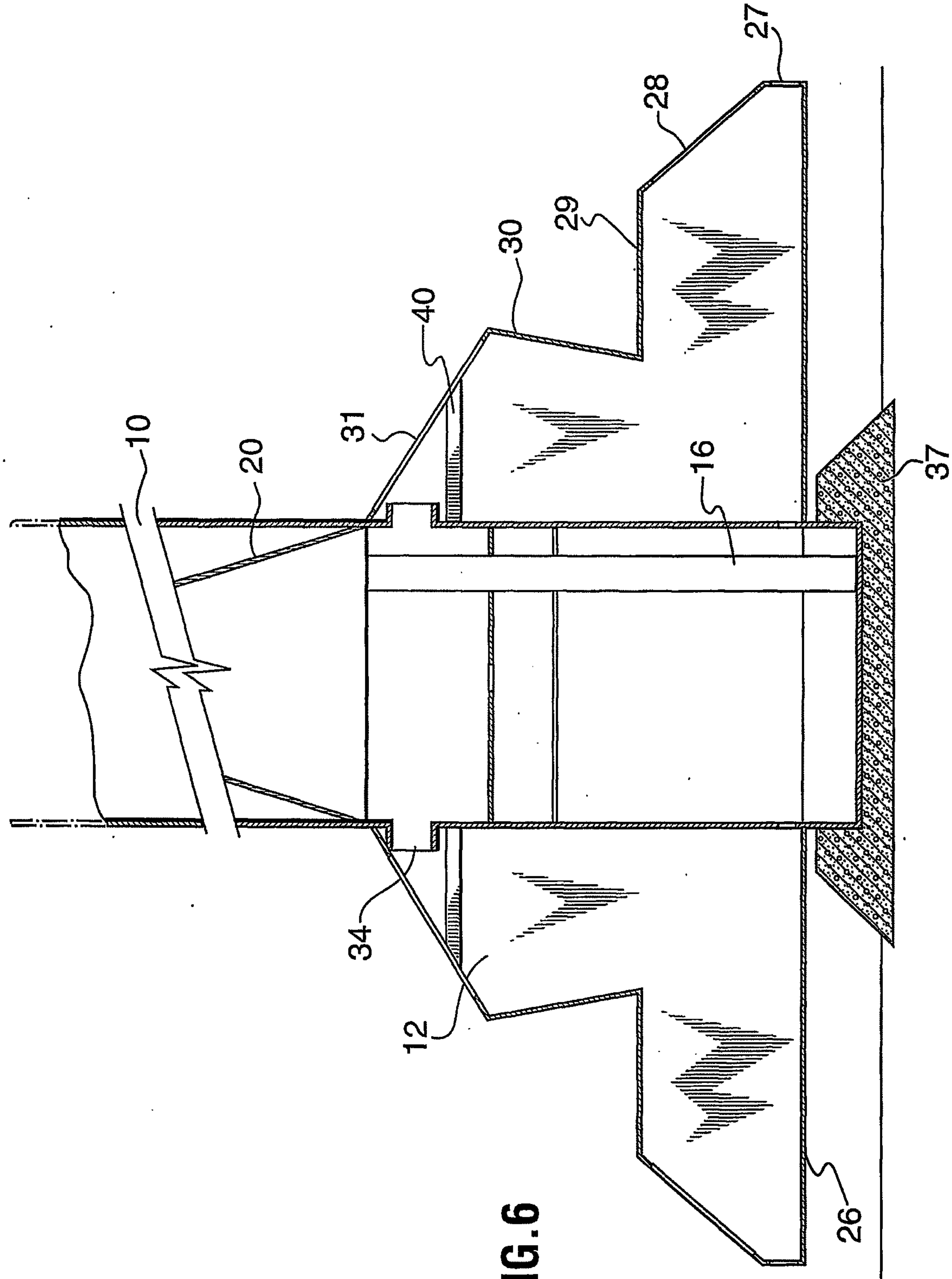

FIG.6

INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F03D1/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F03D F26B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	page 1, line 1 -page 2, line 10; figure	5,7-12
Y	FR 2 530 297 A (SOMDIAA) 20 January 1984 (1984-01-20)	1-4,6
Y	claim 1; figures	5,7-12
Y	US 3 979 597 A (DRUCKER ERNEST R) 7 September 1976 (1976-09-07)	1-4,6
Y	column 4, line 46 -column 5, line 3	5,7-12
Y	US 4 452 046 A (ZAPATA MARTINEZ VALENTIN) 5 June 1984 (1984-06-05) column 4, line 15 column 5, line 1 - line 27	5,8,9

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 October 2001	09/10/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Criado Jimenez, F

INTERNATIONAL SEARCH REPORT

ational Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
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(56) Documents cited
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GB 501540
US 4211084A
US 4079264A
US 4070131A
US 3936652A
(58) Field of search
F1G
F1T

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London, WC2A 3LS.

(54) System for the obtaining of energy by fluid flows resembling a natural cyclone or anti-cyclone

(57) The system comprises a cyclonic conversion tower (23) constituted by a group of convectors situated round an axis toward which there are directed vortical membranes or screens contained in trumpet-shaped revolution bodies. At its top or bottom the tower optionally bears deflectors (10) which increase output. Devices such as turbines (9, 24) for conversion into electrical or mechanical energy of the flow kinetic energy are provided. The tower may be situated on a base which permits the passage of solar radiation (21) with the aim of utilizing its energy, the assembly being completed by a combustion heating system for alternative use. The base may include a tank (44) supplied with hot water and saturated air from a solar heated pre-evaporator (30), the saturated air being drawn up the tower (23) where desalinated water is separated out at condensers (27).

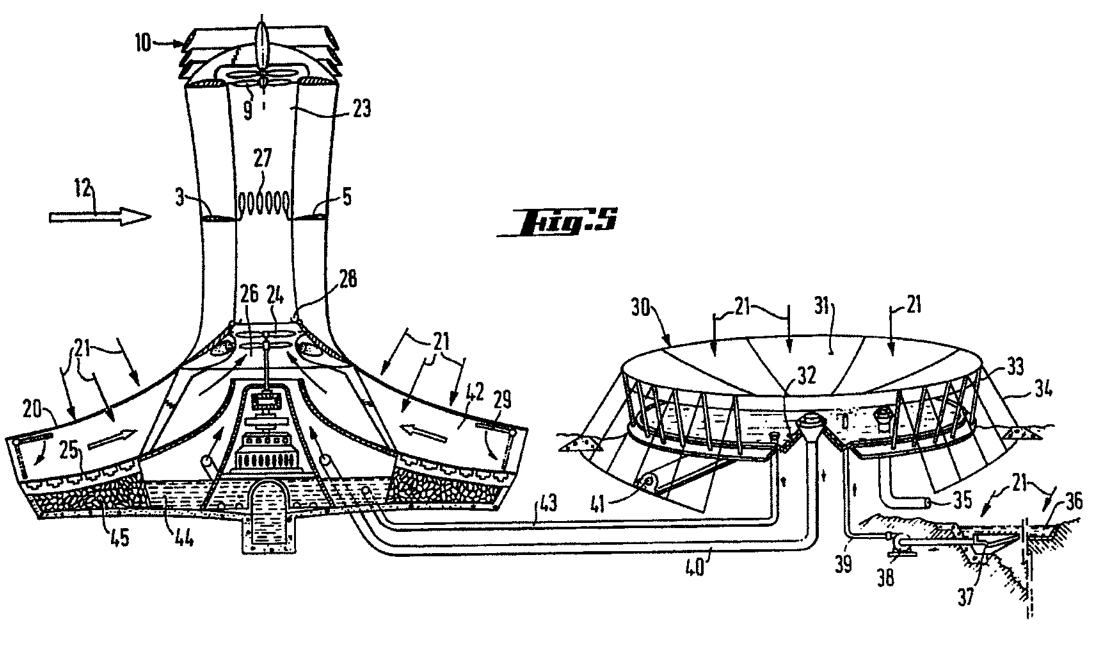

Fig.5

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Fig. 1

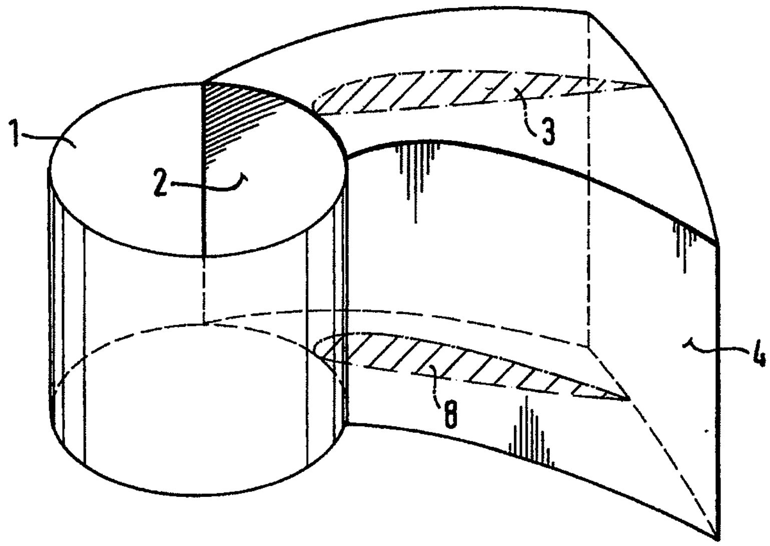
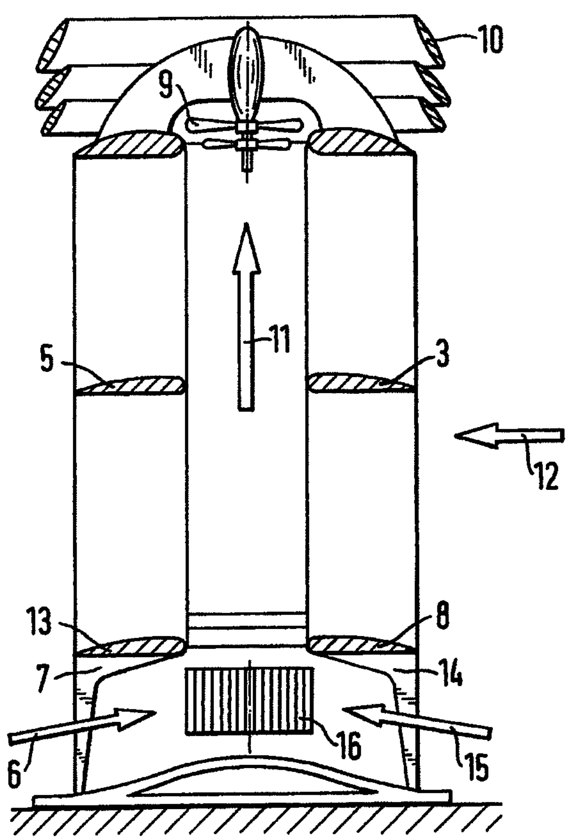


Fig. 2



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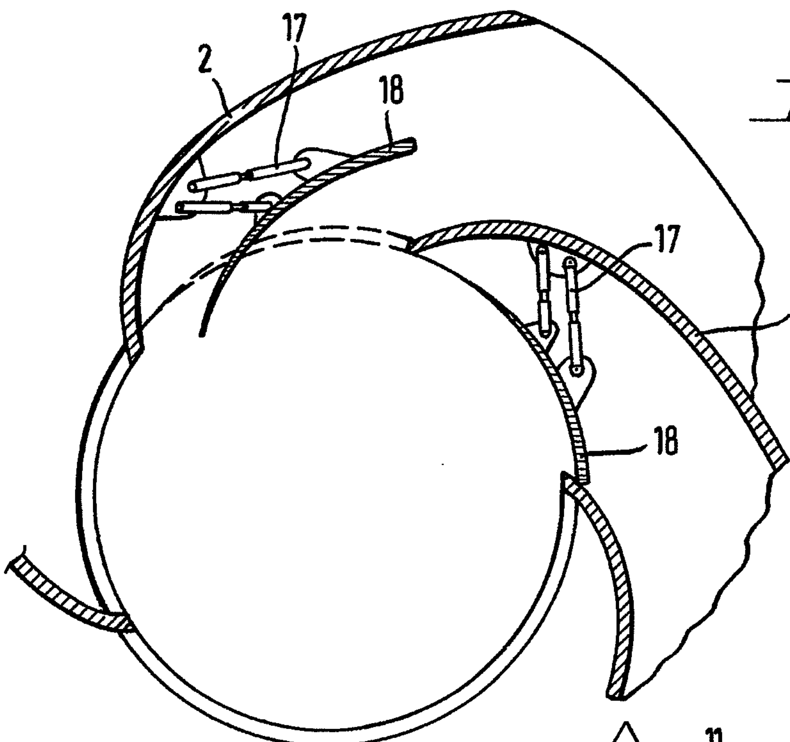

Fig. 3

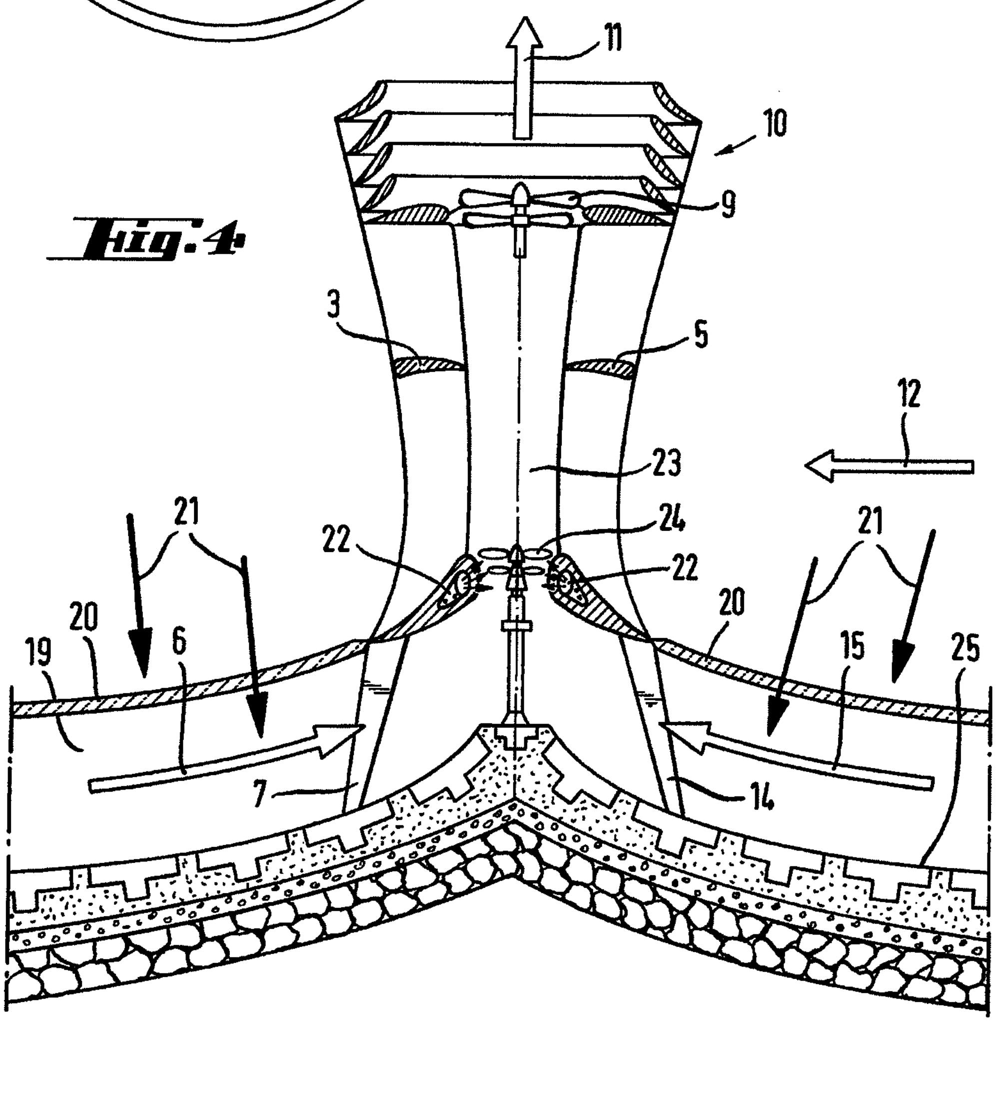

Fig. 4

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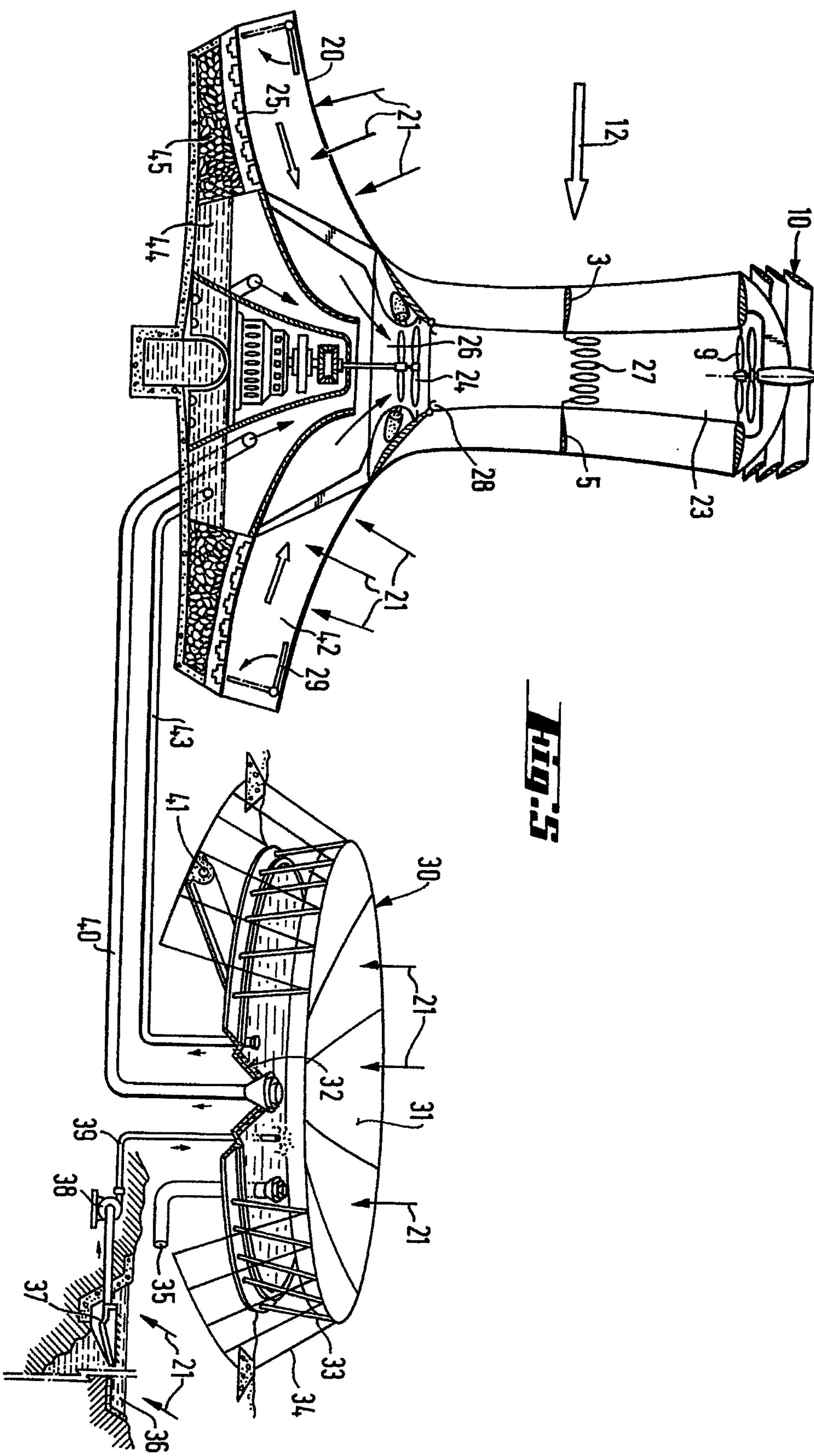

Fig. 5

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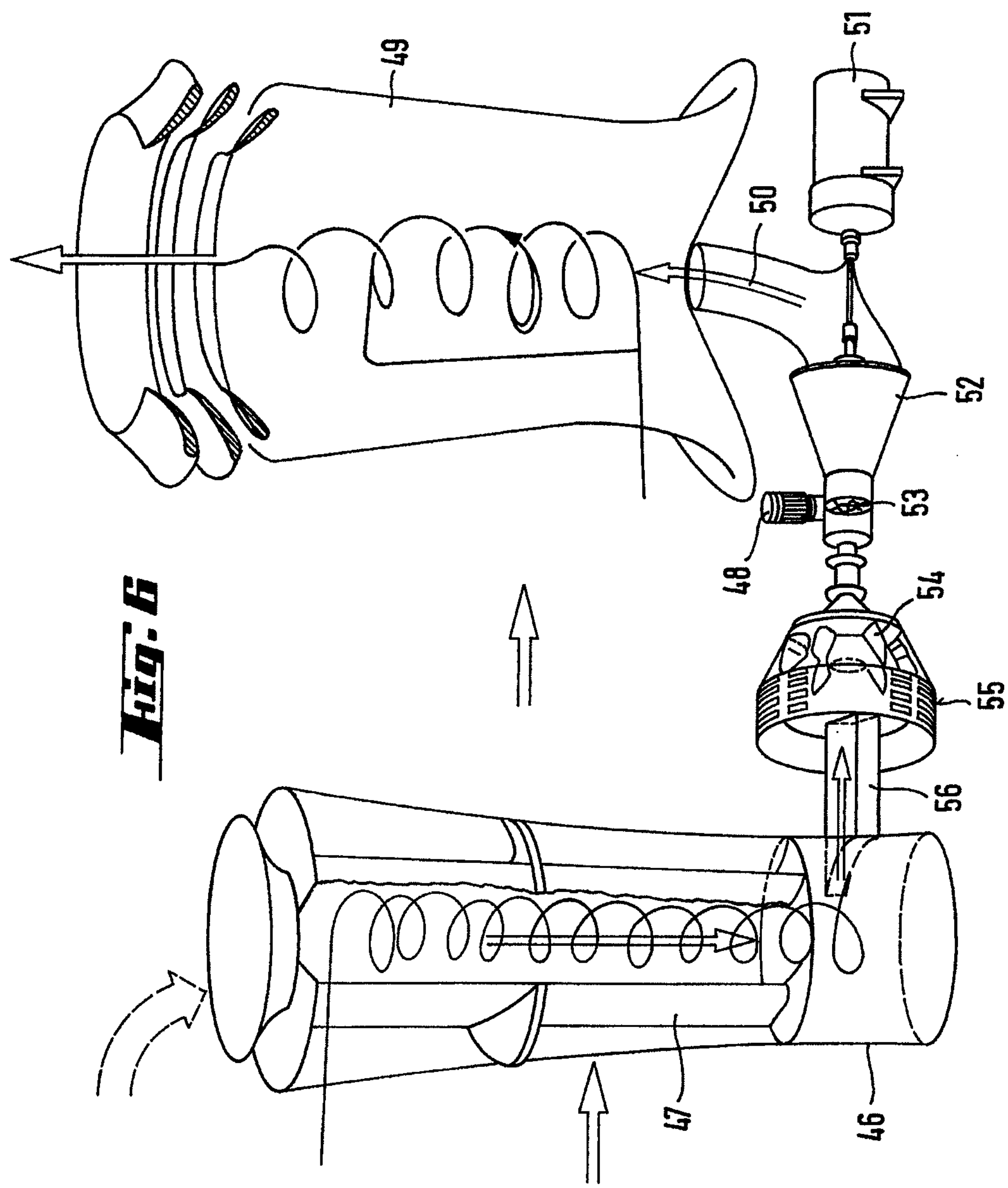

Fig. 6

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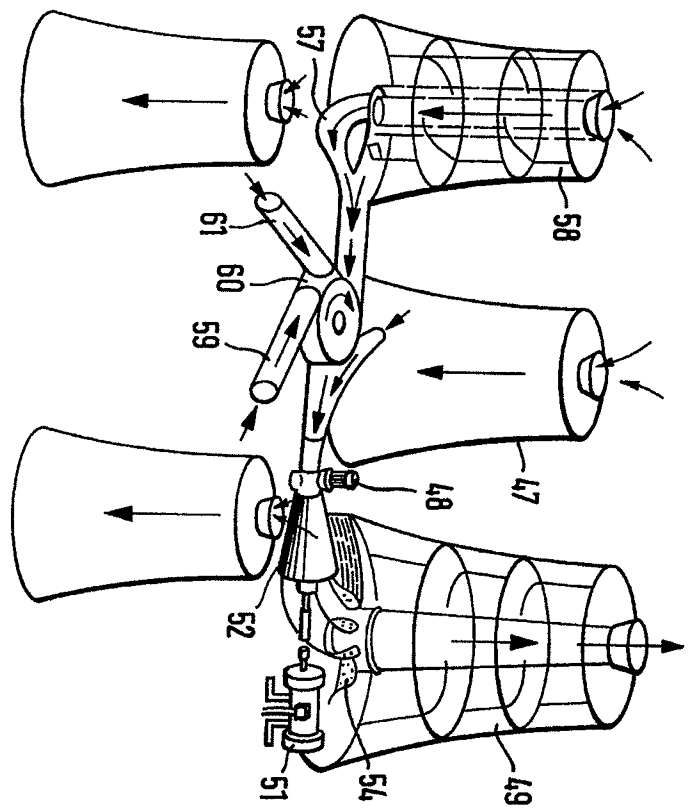

Fig. 7

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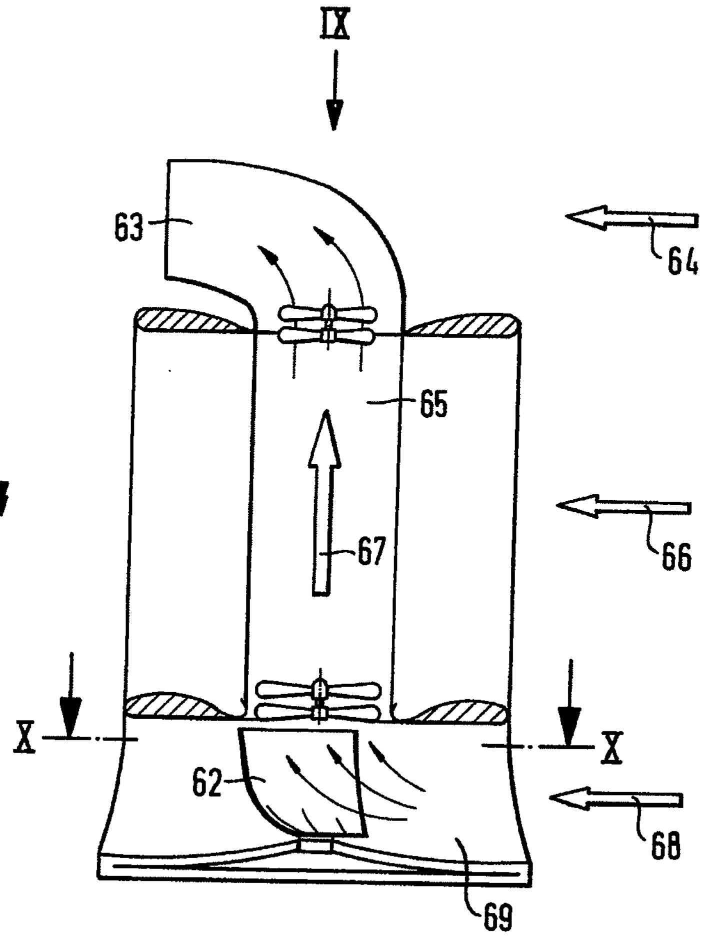

Fig. 8

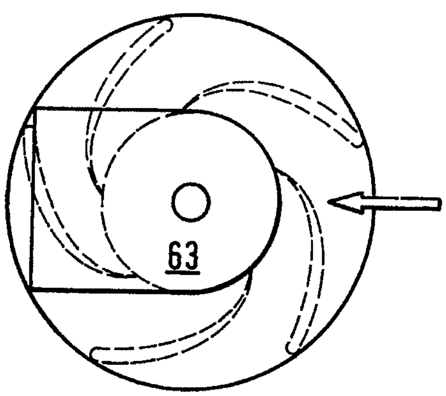

Fig. 9

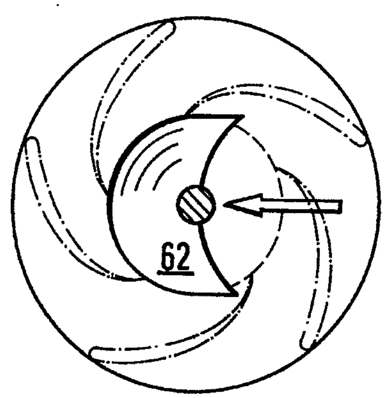

Fig. 10

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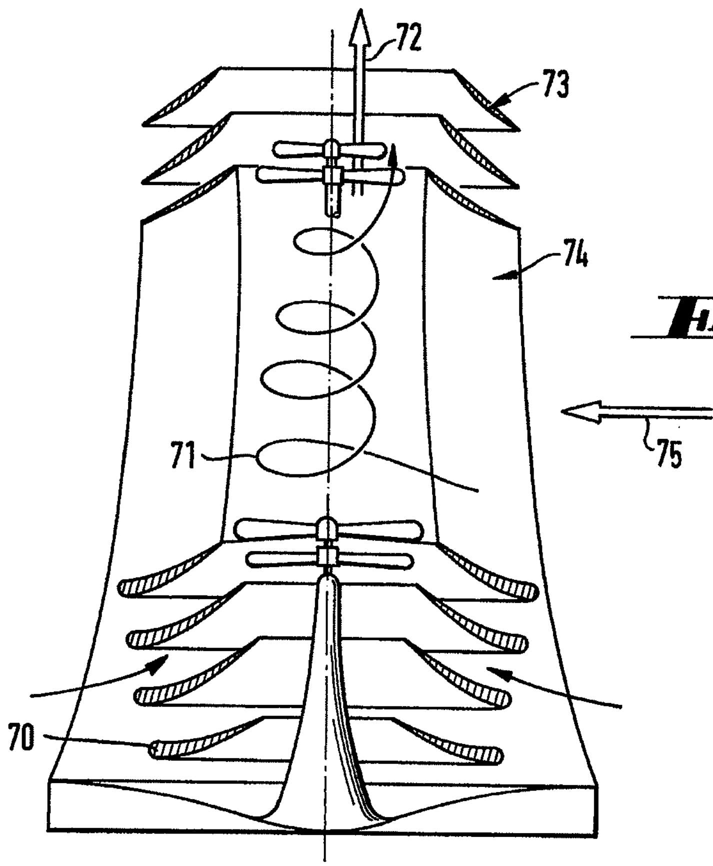

Fig: 11

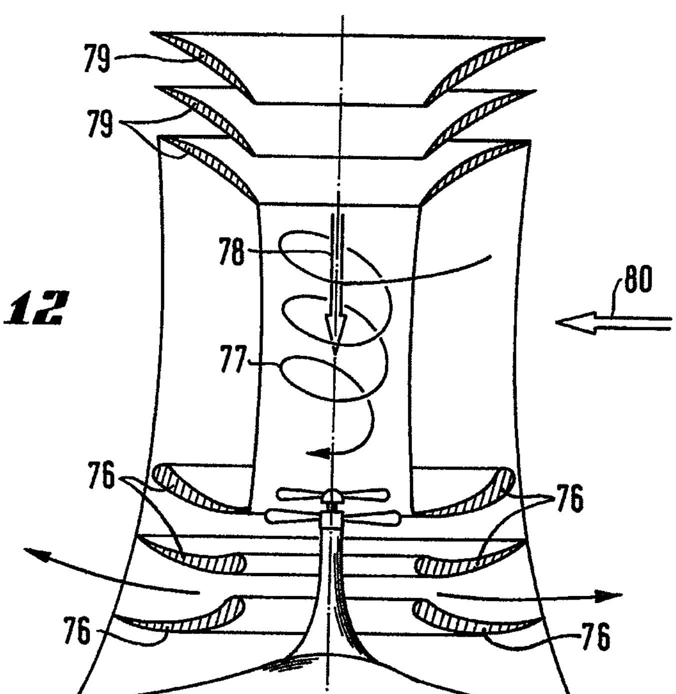

Fig: 12

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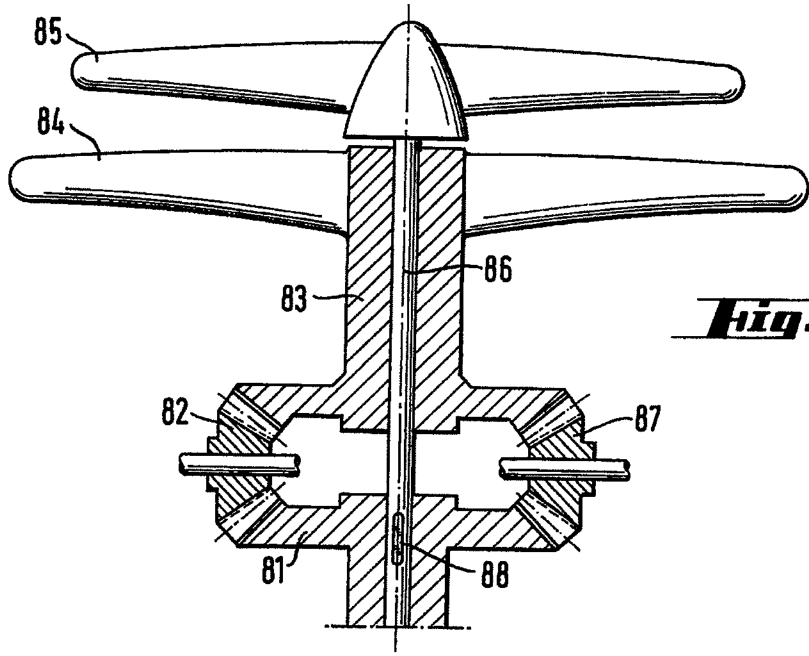

Fig. 13

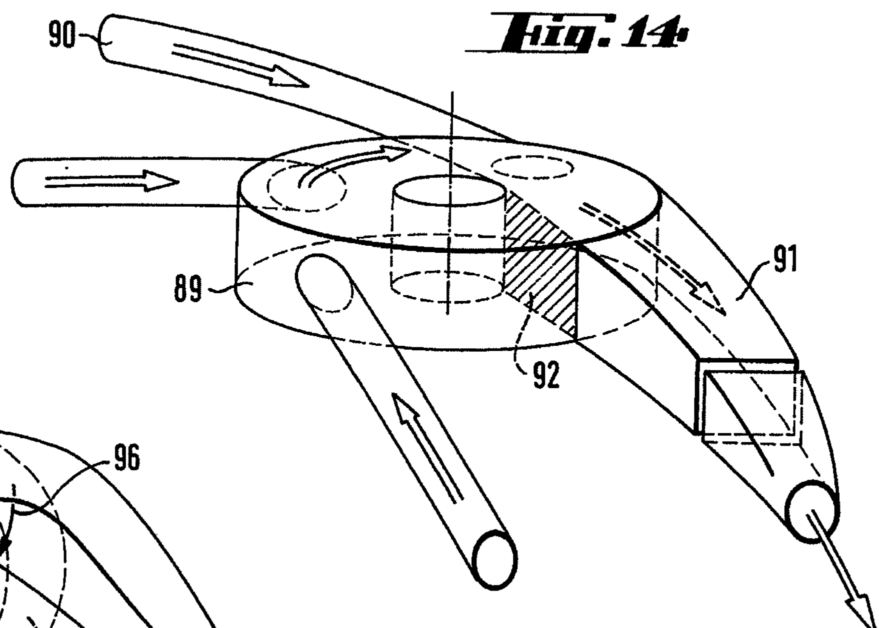

Fig. 14

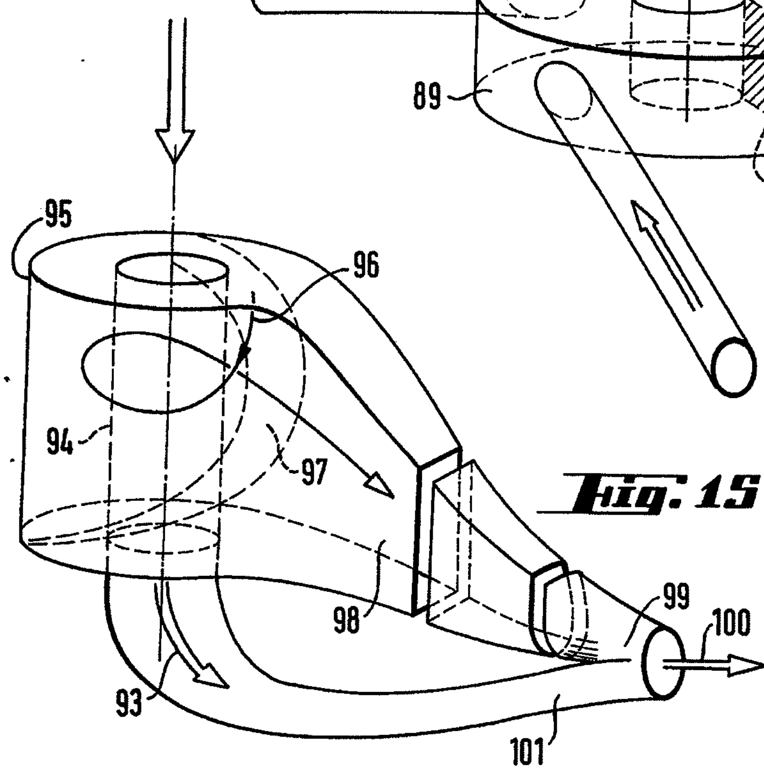

Fig. 15

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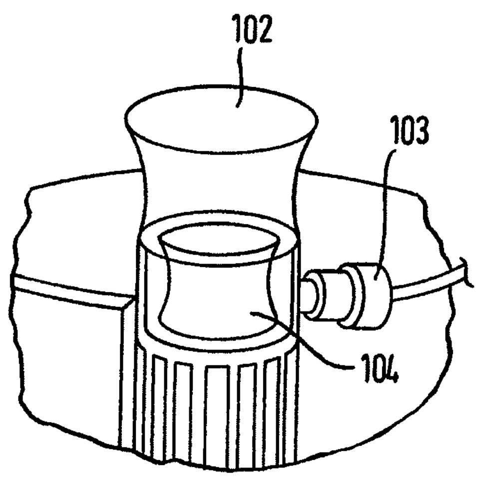

Fig: 16

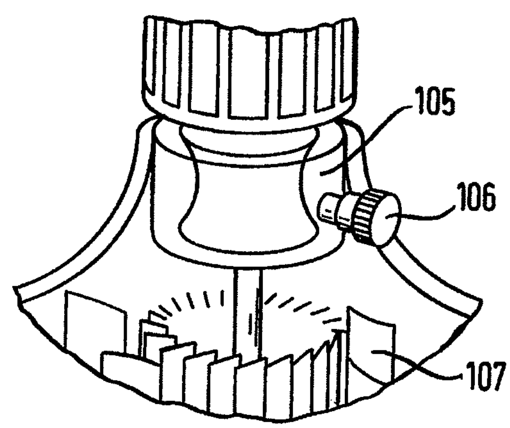

Fig: 17

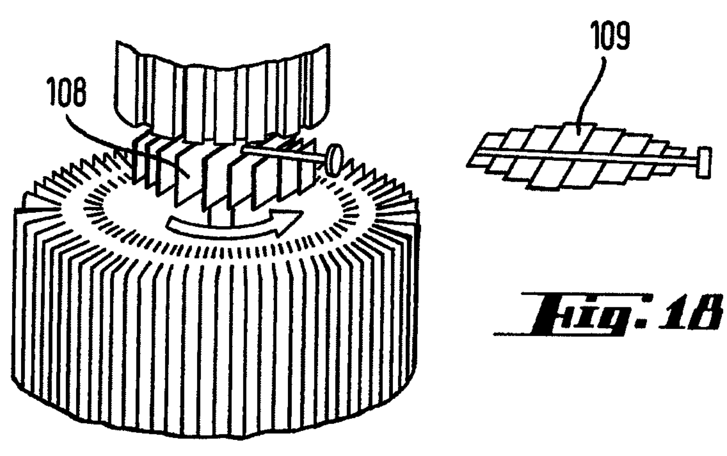

Fig: 18

SPECIFICATION

System for the obtaining of energy by fluid flows resembling a natural cyclone or anti-cyclone

Background of invention

This invention relates to a system for the obtaining of energy by means of fluid flows similar to those forming a natural cyclone or anti-cyclone which permits coverage of the whole range of powers required by humanity, its origin being such that it can be installed in any location. The energy obtained with the system protected by this Patent is produced by the artificial reproduction in suitable structures of confined vortices having a cyclonic configuration from the kinetic energy originating from flows or by taking advantage of the pressure differences existing in the atmosphere as well as the components due to the thermal gradients existing therein. This system permits known phenomena such as cyclones, tornados, typhoons, whirlwinds, etc. to be reproduced by analogy and allows the energy produced therein as well as desalinated water to be obtained. For the description of the system, we will make use of a concrete example of the design to which there correspond the enclosed figures presented as embodiments, which are not intended to be limiting since the specific data in each case are in accordance with the requirements of the design, without the modifications in detail affecting the essence protected in a general manner by the present registration.

Summary of the invention

The system described differs from the prior art in that it allows use to be made of 83% of the energy is contrast to the considerably smaller percentages obtained at present with wind systems, due to the fact that the entering flow is subjected to convective acceleration by natural causes, consequently producing the three basic flows of a natural cyclone which are: the convective flow accelerated by the flow of continuity, the non-rotating flow and the rotating flow, which permits vortical nuclei of limited size to reach very high degrees of energy concentration without design limits in the size of the structures used.

One of the fundamental elements for the artificial production of cyclones or anti-cyclones is constituted by the convectors composed of two vertical membranes or screens which are almost tangential to a central cylindrical duct whose generatrices follow a curved profile in such a way that their presence, together with the central duct, causes in the flow an acceleration defined by the laws of aerodynamics, compelling the natural wind to increase its velocity, accelerating at three consecutive points which are: the curved screen, the actual convector and the vortical duct. These convectors are at any level, without communicating with the flow at the floor or foundation level of the system and are intended to convey, deflect and accelerate convectively a substantially horizontal transverse flow.

The system permits the reproduction in suitable structures of confined artificial cyclones which, in the same manner as natural cyclones, make use of the solar energy as well as the kinetic and thermal energy in the atmosphere.

Similarly, this system permits different thermal exploitation of sea water to be integrated in a technological device encompassing wind, radiant solar and thermal sea water energy, creating a transformation which uses not only the kinetic energy of the wind but also the position or baric energy, the thermal energy of the air depending on its degree of saturation by water vapour and the thermal energy of sea water.

A secondary, but important aspect is the obtaining of desalinated water by the cyclonic conversion process in units which operate with a secondary suction flow of air saturated with water vapour.

As we have stated, cyclonic conversion is characterised in that it transforms horizontal energy flows into vertical energy flows, absorbing or not absorbing in the said vertical flow other flows originating from other energy sources such as radiant solar energy or marine thermal energy.

Brief description of the drawings

Other features of the invention will be apparent from the following description by reference to the accompanying drawings, in which:-

Figure 1 shows a vortex duct of a cyclonic tower;

Figure 2 is a diagrammatic view of a cyclonic or anti-cyclonic tower;

Figure 3 is a cross-section through a tower of convectors showing vertical screens and blocking devices;

Figure 4 is a fragmentary view of an energy converter unit;

Figure 5 illustrates another form of cyclonic tower;

Figure 6 illustrates a combined cyclonic - anti-cyclonic synergetic system;

Figure 7 is a diagrammatic representation of the mode of connection of units as shown in Figure 4;

Figure 8 is a diagram of an arrangement of deflector diffusers;

Figure 9 is a plan view of the arrangement shown in Figure 8;

Figure 10 is a section on line A-A of Figure 8;

Figure 11 shows a cyclonic conversion device with fixed concentric screens;

Figure 12 shows an anti-cyclonic conversion device;

Figure 13 shows a force rotation reversal device;

Figure 14 shows a flow collector;

Figure 15 shows a decyclonizing device; and

Figures 16, 17 and *18* show alternative forms of flow regulation devices.

Detailed description of the invention

Cyclonic towers are composed fundamentally of convectors with their vortical duct as in the drawing in Figure 1 which shows vertical membranes or screens 4 and 2 joined together by stiffeners constituted by horizontal plates with streamlined sections 3 and 5. The vertical screens 4 and 2 of which there are two per convector are generated over a curve such as a circumference, ellipse, hyperbola, parabola, logarithmic or hyperbolic spiral or any other

type, to a suitable height, and between each two consecutive screens there is formed a convector which concentrates the flow of energy flowing to the vortical duct 1 divided by all the convectors if there are more than one. A cyclonic or anti-cyclonic tower is constituted by one or more convectors like the one just described which are formed between two stiffeners and two consecutive screens forming various levels, the tower being cyclonic if the fluid turns in an anti-clockwise direction and anti-cyclonic if it turns in a clockwise direction, in the northern hemisphere.

Figure 2 shows a diagrammatic cylonic or anti-cyclonic tower. Four stiffeners 3, 5, 8 and 13 and the tower-supporting piles 14 and 7 can be seen therein. In this Figure the arrow 12 indicates the direction of the wind entering the tower and the arrow 11 the direction of the flow making this tower a cyclonic tower as the direction is from bottom to top. The flow also enters in the directions indicated by the arrows 15 and 6, which flow actuates the relevant converter device which, in Figure 2, is a turbine 16 at the bottom, an assembly of propellers or blades 9 being situated in the upper portion, of which the rotors are contra-rotating and are at the top of the tower inside the diffusers 10. The deflectors would be situated in the lower portion of Figure 2.

Devices for transforming the kinetic energy of the flow into electrical or mechanical energy, such as pumps, generators, compressors, dynamos, alternators, etc. are situated without distinction at either of the ends or at both ends, both at the base and at the top of a tower of convectors.

Figure 3 shows a cross-section through a tower of convectors, showing the section of the vertical membranes or screens 4 and 2 as well as the blocking devices 18, for blocking the intake of the flow into the vortical duct resting on the damping arms 17 turning about the support and opening when they are located at the convector which should permit the passage of fluid by attracting it in the direction of the wind, providing that the streamlined profile of the blocking device positions it in such a way that it has the minimum resistance thereto and, nevertheless, shuts itself when the fluid attempts to circulate inside the convector towards the exterior from the vortex already created. The blocking devices turn when the air enters a convector in such a direction that it pushes the blocking device from the outside inwards causing it to be located in the position having least resistance to the intake of air, whereas it remains closed when the air travels from the inside outwards, keeping this given convector blocked. They have one or more recovery damping devices which are actuated in a suitable direction by the actual flow.

If the blocking devices lengthening the membranes beyond their tangent to the flow until they form part of the vortical duct are removed from the convectors described with reference to Figure 3, convectors will be obtained which can be used for units in which the power will be up to 5 kilowatts and the output will be of little importance with the considerable advantage that moving parts will be eliminated.

If the cyclonic conversion tower described above is provided at its base with a face 20 (Figure 4) permitting the passage of solar radiation 21, for example glass, plastics etc., preventing reflection to the ambient air we will have retained, in the scope of secondary suction by the cyclonic converter due to the known hothouse effect, the radiant solar energy in the form of unstable hot air.

To increase the radiant heating effect of the solar cyclonic system, the system will comprise, at its base, a thermally absorbent black bottom 25 made of a material capable of accumulating heat.

The energy converter 24 which, in Figure 4, is constituted by two propellers mounted on contra-rotating axles, receives the flow of thermal and kinetic energy. There are therefore two energy vectors in the displacement of the flow outside the vortical duct; one thermal vector and the other by transposition of kinetic energy in the main flow.

The heat accumulator and the thermally absorbent black bottom 25 constitute a regulating element which accumulates the heat during the day, giving off surplus at night and thus balancing the thermal wind.

The thermal energy plus the transposed kinetic energy give to the energy converters 24 and 9 in Figure 4 their combined energy under the regularizing interactive influence of the paravortical flows created reciprocally.

To regularize the use of the installation in calm or cloudy climatic conditions, the tower with conversion of radiant solar energy is provided with an artificial heating aid based on burners 22 of gases of liquid fuels arranged in such a way that the entry of the hot gases of combustion will take place tangentially and horizontally at the base of the vortical duct 23 and with such an arrangement that the exhaust gases create an artificial vortex with suction at the secondary suction base 19 after having actuated the blade-type converter 24.

In a unit like the one just described, it is possible to use radiant solar energy and optionally thermal energy originating from combustion together with or distinctly from wind energy.

A unit like the one described with reference to Figure 4 is provided with a base in the form of a tank having a low level of water 44 (Figure 5) which receives hot water and saturated air from some pre-evaporators known as hydric hothouses 30 with a black thermally absorbent bottom 32 which are covered by a transparent surface 31 constituting the membrane sheet covering which forms hothouses over the surface or sheet of water supplied with water from a large natural or artificial sheet of water 36 preheated by the sun's rays 21 and trapped by the surface sea water collector 37 pumped by the pump 38 which reaches the hydric hothouse 30 through the pipes 39 located above the thermally absorbent bottom 32 and is heated even more by the sun's rays 21 striking the membrane sheet covering 31. This air is sent through the pipe 40 connected to the saturated air inlet to the top of the tank 44. In the same way, the said tank 44 is filled by means of the pipes 43 with hot water from the hydric hothouse 30 of which the covering 31 is supported by the pillars 33 and tightened by the tension rods 34. The

ambient air enters the above-mentioned hothouse via the duct 35, the duct 41 serving for the extraction of salt. In the tank enclosure 44 and due to the water received by it through the duct 43 and the saturated air reaching the top from the hydric hothouse 30 through the duct 40 it is possible to create the thermal conditions of a natural cyclone at the base of the cyclonic converter.

Using these devices it is possible to integrate the kinetic energy of the wind, the radiant thermal solar energy, the energy produced by combustion, in the base of the vortical duct, of gases or liquid fuels, the energy of the hot water at the surface of the sea due to saturation by hot air and the energy obtained by insulation of hydric hothouses.

As they can all be integrated easily, the maximum natural energy available can be extracted at any moment whether it is wind, solar, or thermal, from the sea. In the absence thereof, it can be supplied by liquid and/or gaseous fuels, thus making the system independent from the prevailing climatic conditions.

In the tower illustrated in Figure 5, the kinetic energy of the wind creates a depressed column drawing in the unsteady hot air generated by the solar hothouse 20, the thermally absorbent surface 25 and the accumulator 45. The rising column of air sucks saturated hot air from the pipes through 26 while the hot water enters through the tubing 43.

The most suitable mixtures of saturated air and dry air 42 can be made by means of the blocking devices 29 acting as throttling deflectors for the secondary suction ducts 40.

This cyclonic tower which can be completely regulated lifts a column of saturated air by means of the depression created by the kinetic energy. The condensation of this air at a given height of the cyclonic conversion tower can produce at will condensed and desalinated water which is gathered in the thermal condensers 27 and is collected in the receivers 28 by means of suitable channels or pipes.

The heat of condensation imparted to the column of rising air reinforces the rising flow of the vortical flow, increasing the depression column and the paravortical flows. The rising thermal column generated in this way can therefore replace the kinetic energy of the wind up to the level of a confined and established cyclone.

The condensation of the saturation water from the sucked air provides the system with an external thermal energy source which keeps the confined cyclone in motion even in the absence of paravortical winds, that is to say the fundamental kinetic flow used for the priming and unleashing of the cyclone. Sufficiently large hydric hothouses 30 provide a natural and economical system for trapping solar energy and transforming it into the kinetic energy of rising air which can be used and transformed in a converter with turbines, propellers such as 9, etc. to produce electrical power.

The air from 42 as well as the air at the top of 44 collects and rises through the vortical duct 23 actuating the propellers 24 as it passes through them. This Figure also shows that the rays 21 heat the solar hothouse 20, and stiffeners whose branches 3 and 5 are streamlined, which form part of adjacent convectors traversed by the air from direction 12.

All the components described up until now with reference to Figure 5 can be used together or separately.

Of course, the arrangement shown in this Figure is neither restricting nor limiting, and the dry hothouse, the hydric hothouse and the burners can be arranged in any manner providing that the physical effect of regulation and integration of the flows are combined in an ascending driving vector of the air column propelling the elements for converting the energy received into electrical energy, such as turbines, propellers etc., which are coupled to the said generators or other means of exploitation such as pumps, compressors or accumulators.

In a manner similar to that in which cyclonic towers are produced, an anti-cyclonic tower is obtained if the rotational direction of the entering air is reversed, with the characteristic inherent in it and in our hemisphere that the vortex will travel from top to bottom instead of from bottom to top as things happen in the opposite direction in the other hemisphere.

Figure 6 shows a combined cyclonic-anti-cyclonic system which is synergetic. The method of making use of the combined effects of a cyclonic tower and an anti-cyclonic tower will be described with reference to this Figure. In fact, by connecting a decyclonizer 46 to an anti-cyclonic tower 47, the flow will be sent through a duct 56 traversing an energy converter 52 which actuates an electric generator, for example 51, continuing to travel in the direction of the arrow 50 where it is sucked through the cyclonic tower 49. The system is completed and improved by a combustion module 55 provided with burners 54 which supply energy when the climatic conditions do not assist operation of the system.

Finally, a plate diaphragm 53 which is operated by a hydro-pneumatic servo-mechanism 48 opens or closes the suction duct, thus controlling operation and including the power of the system.

When the axes of the cyclonic and anti-cyclonic towers are spaced apart as viewed in the direction of the prevailing flow, the space being known as "disturbance length", the system is such that the second tower, aligned with the main uniform flow, receives the flow already disturbed in velocity by the first tower, the energy per unit area of collection in the second tower being increased significantly due to the higher velocity of the flow disturbed by the first tower in the direction of the flow.

The cyclonic system combined with the anti-cyclonic system with a disturbed rate in the flow demands the bringing together of the conversion units (towers) while the conventional propeller system demands the separation of the propeller supporting towers.

In this case, it is found that, unlike what happens with the conventional propeller-type converters when one flow is caused to act upon another, the combination of the two towers collects more energy than each tower would collect individually.

A dual combination like the one just described is suitable for single-direction flows like those existing in mountain gorges for catabatic flows or in coastal

zones for thermal winds.

These combined cyclonic-anti-cyclonic systems are obviously improved by removing some screens located on the leeward or windward side between the towers or by substituting them by guide screens. The optimum disturbance length is a function of the prevailing mean velocity of the flow. The distance at which this phenomenon takes place with maximum intensity will be called "induced disturbance length".

The compound or combined arrangement of the symmetrically reciprocal cyclonic-anti-cyclonic systems permits high density energy collection and conversion systems for wind energy to be concentrated over relatively small areas. This phenomenon is identical to and has the same causes as the disturbances in the wind between high-rise buildings.

Figure 7 shows diagrammatically the connection between the various units such as those described above which are spaced apart at distances known as induced disturbance length which, as already stated, is the distance producing the optimum output, the units being situated in such a way that their distribution is similar to the pattern of winds and velocities prevailing at the location. This multiple combination results in an induced disturbed flow which we will call for short "poly-fluper" (from poly-flujo-perturbado), which produces a high output in the concentration of wind energy since this arrangement is the most suitable for the construction of large power stations based on wind energy, producing levels of installed power similar to those of large thermal, hydraulic or nuclear power stations.

Figure 7 shows an example of a multiple combination for omni-directional wind comprising a cyclonic unit and several anti-cyclonic units distributed in a horizontal plane over the pattern of prevailing winds and directions, illustrating how various anti-cyclonic units, 58 with its decyclonizer 57 and the anti-cyclonic unit 47 and those arriving via 61 and 59, converge in the collector 60, the energy originating therefrom traversing the diaphragm regulated by the servomechanism 48 and then arriving at the energy converter unit 52, actuating the electrical generator 51, and passing through the duct with burners operated by hydrogen or a different fuel 54 situated around its periphery, finally traversing the cyclonic module 49 in which the flow therefrom is combined with the earlier flows producing the maximum energy.

In the following we will describe in sufficient detail some of the components of the systems forming the subject of this specification:

- The devices blocking the vortical duct tend to close when the air attempts to issue outwards from the vortical duct and to open when the air tends to pass towards the vortical duct.

Although deflectors and diffusers have opposing functions, in the cyclonic-anti-cyclonic energy system, due to the axial symmetry of the flows in each, the designs can be identical with a deflector for channeling and concentrating the flow in the case of an anti-cyclonic flow whereas the opposing function of distributing and diffusing the issuing flow into a uniform flow can be fulfilled in a cyclonic system.

Figure 8 shows a diagram of such an arrangement with several deflector diffusers with tubular bends, with the aim of increasing and improving the energy collection and conversion capacity of the installation.

Although the structural geometric relationships are different, in order to produce an omni-directional orientation relative to the wind which is suitable in both cases, the principle is the same.

Figure 9 shows a plan view of Figure 8, and Figure 10 is a section along line A-A in Figure 8.

The flow from 68 which enters at 69 (Figure 8) covers the secondary flow sucked in by the vortical duct 65 in a cyclonic system from the wind travelling in direction 66. The external flow 64 entering above the diffuser 63 also creates a leeward depression which assists the suction and diffusion of the issuing flow. This produces the geometric addition of the energy vectors generated by 67, 69 and 64, which are all in the same direction.

This Figure shows clearly that the diffuser which acts as a diffuser at 63 acts as a deflector at 62.

When changing hemisphere with the same system, the deflectors act as diffusers and the diffusers act as deflectors, and they are all utilized for the first time in these cyclonic and anti-cyclonic systems and they can be either capable of orientation or static and concentric like those shown in Figure 11 which shows a cyclonic conversion device with fixed screens 74 which form the corresponding convectors provided with blocking devices such as 18 (Figure 3) which oscillate in the direction of the main flow. In the case which we are describing with reference to Figure 11, the deflectors and diffusers can be constructed in the form of a disc with an orifice in the centre and with a streamlined cross-section, parallel to each other converging and/or diverging from the inside out or from the outside in, depending on whether they have the function of diffusion or deflection (Figure 12). In Figure 11, in the case of a cyclonic system converting a horizontal wind 75 into a vortex 71 with propulsion in direction 72 and in the northern hemisphere, 73 would be a top diffuser which would collect the flow at the top, preventing the occurrence of horizontal shearing forces when the vortical flow leaves the tower and thus helping the soft leeward shift of the vortex and its diffusion in the uniform main flow.

The base deflector 70 acts similarly at the base, preventing the formation of low pressures. In this case, the significant difference can be convergence in the diffuser or diffusers and divergence in the deflectors, as shown in Figure 12 which illustrates an anti-cyclonic system.

In Figure 12, the incident energy flow 80 rotating in a clockwise direction 77 causes a descending flow 78 toward the energy converters. The head deflectors 79 compel the flow to descend through a vortical duct while the base diffusers 76 create a depression due to their convergence which helps the exit of the descending flow.

The deflector diffuser is consequently formed by one, two or more discs of variable size with a concentric orifice in the centre thereof with a stream-

lined cross-section which converges and/or diverges from the inside out or from the outside in, depending on whether it acts as a diffuser or deflector.

In the northern hemisphere, with an anti-cyclonic system according to Figure 12, the deflectors 79 diverge towards the centre whereas the diffusers 76 converge towards the axis.

Deflector diffusers of the venturi or cylindrical or hemispherical type with doubly swinging plates are obviously also utilized frequently and are widely used in these systems as well as deflector diffusers combined with all those mentioned up until now.

In order to transform and utilize the energy in the transposed flow (or secondary vortical ascending or descending, linear or rotating flow), there are used various devices such a double or single concentric, contra-rotating turbines as well as conventional propellers or propellers modified according to the geometry and the flow of the path of the lines of the energy current, or double, contra-rotating propellers arranged in the secondary flow to make use of the sucked or propelled flow or the ascending thermal flow, if any, for the cyclonic or anti-cyclonic systems described herein as well as the main paravortical or substantial horizontal flow.

Other possible devices include turbines with multiple blades and a fixed or rotating deflector for air and/or hot gases in simple cyclonic installations, combined anti-cyclonic installations or multiple polyfluper installations.

In all cases, the use of simple propellers or turbines for the conversion of the transposed or induced energy flow produces a low collection capacity of the order of 59% maximum. In order to improve this capacity, double contra-rotating energy converters are connected to the cyclonic and anti-cyclonic systems to produce indices of collection of approximately 83%.

For this purpose, it is necessary to reverse the direction of rotation of the resultant force by combining it with the force of the other concentric device, as shown in Figure 13. In this Figure, the propeller 85, which can be substituted by a rotor or turbine, rotates in a given direction entraining the axle 86, for example, in a clockwise direction while the propeller 84 which entrains the axle 83 rotates in the opposite direction. Owing to the conical gears 87 and 82, this rotational direction in reversed in such a way that the body 81 rotates in the same direction as the axle 86, making the movement of the two axles integral by means of the pin 88.

The flow collector (Figure 14) has the object of channelling and orientating the flows from various anti-cyclonic systems or sucked by the cyclonic system towards the common energy converter, and for this purpose it is constituted essentially by a body 89 whose walls are formed by two concentric or non-concentric cylinders which are closed at the top and the bottom.

The ducts 90 transporting the flow from the anti-cyclonic systems enter this body 89. To produce the cylindrical configuration of the flow, it circulates circumferentially, permitting the subsequent addition of flows from other systems, up to a given point at which a tangential screen 92 is connected to a common outlet duct 91.

The flow from 91 can be connected to an energy converter and to the suction of a cyclonic tower.

When it is necessary to transform the non-rotating and rotating flow of the vortex into a linear flow again so that it can be integrated into the common flow, for example, by decyclonizing and devortizing the said flow, there are used devices which we will call decyclonizers or devortizers, as illustrated in Figure 15 which shows that the device essentially consists of two concentric cylinders 95 and 94 in whose interior there is arranged a conoidal deflecting surface 97 which compels the flow to enter the curvilinear linear duct 98. The rotating flow 96 is composed of the asymmetrical sheet legs 99 with the linearized flow of the vortex 93 descending in the duct 101. This linearized flow 100 can be integrated in the collector with flows from other origins or towers.

By throttling the flow at the beginning or end of the vortical column, the fluid volume in the said column and consequently the energy changes per unit time.

Regulators such as the one in Figure 16 effect this regulation at the head or like the one in Figure 17 at the base. Both devices regulate by means of an elastic cylindrical diaphragm 104 or 105 which is situated at the end or at the beginning of the vórtical column, respectively. With the regulator in Figure 16, the flow reaches the nozzle 102 after traversing the elastic membrane 104, controlled by the servo-compressor and control valve 103.

The regulating devices are formed by a strong external cylinder and another flexible diaphragm-like concentric internal cylinder of which the diameter varies as a function of the pressure and/or vacuum regulated in the interior or cavity of the two cylindrical bodies via a servo-compressor and control valve 103 or servo-regulator 106. The diffuser or deflector devices 107 can be seen at the base.

Figure 18 shows a regulating device which is arranged without distinction at the beginning and/or at the end of the vortical column and which consists essentially of a variable number of flaps or shutters composed of slats which open and close the vortical duct, regulating the flow through the vortical duct. This Figure clearly shows how the flaps 108 located in the Figure correspond to the open position of the regulator whereas the flaps 109 correspond to the closed position.

The irregularity of wind energy means that it must be possible to accumulate the surplus energy in order to satisfy the demand, as in the case of hydraulic energy. One of the basic applications of the claimed system is mass production for the accumulation of wind energy in the same way as solar energy which we will describe separately below owing to its importance.

First of all, a hydro-wind system can be produced in the following manner:

The electrical energy from cyclonic and/or anti-cyclonic power stations can be applied to the operation of reciprocating pumps or turbines or reciprocating generators which pump water from the opposing dams in hydraulic installations so that

the water consumption for the production of electricity is reduced to evaporation or filtration losses.

This arrangement opens up great possiblities not expected hitherto. Firstly, it permits the exploitation of hydraulic basins which, owing to their steep gradient, did not allow large tailings dams and a damming capacity sufficient to justify the installation of hydro-electric power stations. Secondly, in locations where they already exist, it liberates large volumes of water for industrial, agricultural or domestic use which, up until now, had to be available in reservoirs in order to be used for energy.

Since the cyclonic anti-cyclonic system relies on inexhaustible and recoverable wind energy, radiant solar energy and marine thermal energy, it makes it possible to contruct large power stations having a potential level per unit of the order of thermal, hydraulic or nuclear energy, thus altering the accepted premises on the availability of water and energy.

Cyclonic hydrogen system: by applying the energy obtained in cyclonic anti-cyclonic units, with or without assistance, to electrolytic modules supplied with sea water or unhygienic water, it is possible to obtain hydrogen at low cost and this makes it possible to obtain methanol or liquid fuels or, in combination with carbon, hydrocarbons, by means of the relevant technology.

One hydrogen wind unit can produce energy and other valuable products or, in turn, hydrogen, oxygen, all types of salts, and desalinated water.

Just as the hydro-wind system is justifiable in mountainous countries, the hydrogen-wind system is particularly suitable for countries with coastal zones or with internal lakes or landlocked seas.

In view of the characteristics of the invention which is claimed in a general manner and with reference to concrete embodiments, it can be stated that the systems for obtaining energy by means of flows similar to those forming a natural cyclone or anti-cyclone can be constituted by the shapes and sizes considered to be most convenient and by the most suitable materials for each concrete application, without variations such as those which might occur in details of presentation and finish affecting the essence claimed, since the systems constructed in accordance with such characteristics with any of these modifications will only be variations which are also included and protected by the present registration.

CLAIMS

1. An energy conversion system utilising cyclonic or anti-cyclonic fluid flow comprising:

a cyclonic conversion tower having an axial fluid flow vortex duct;

one or a plurality of air flow convectors spaced vertically in the tower for concentrating flow of fluid laterally into the tower into axial flow along said duct;

means at one end of the tower for augmenting fluid flow output;

devices at the top and bottom of the tower for converting kinetic fluid flow energy into another mode of energy;

a base which supports the tower and admits solar energy for utilisation to augment the energy output of the system; and a conventional heating system for alternative use.

2. A system according to claim 1 wherein the convectors each comprise two vertical screens generated by profiles which are tangential to the direction of flow and are joined together by stiffeners having a streamlined profile, the screens merging into the said vortex duct.

3. A system according to claim 1 wherein the convectors each comprise two vertical screens generated by profiles which are tangential to the direction of flow and are joined together by stiffeners having a streamlined profile, said system further comprising fluid flow blocking devices mounted on damping arms and turnable to and from positions in which they prevent fluid flow into or out of the vortex duct.

4. A system according to claim 1 wherein each said convector is a hollow body formed by curvilinear and truncated pyramidal surfaces;

said system further comprising fluid flow blocking flaps which are each movable about a vertical axis and equipped with a damping device, and servo-mechanisms - for concentrating the power due to the fluid flow to the convectors.

5. A system according to claim 1 wherein said base incorporates a solar radiant wind energy unit adapted to generate a rising flow of fluid for integration with the lateral fluid inflow and said heating system utilises a fluid fuel to generate or augment rising fluid when climatic conditions result in an insufficient supply of solar energy.

6. A system according to claim 5 and comprising a low level water tank at the base of the tower, said tank being supplied with water which has been preheated in an hydric hothouse with a thermally absorbent black bottom, said base having channels for collecting condensed air and de-salinated water vapour deposited from the tower.

7. A system according to claim 2 in which the screens are symmetrically arranged about the tower axis with their curvature in the same direction whereas deflectors and diffusers at the head and base of the tower are non-symmetrically arranged and thereby create an anticyclonic flow of fluid from the top to the bottom of the tower.

8. A system according to claim 1 which includes also an anticyclonic conversion tower combined with the cyclonic conversion tower by coupled fluid flows such that propulsion of anti-cyclonic conversion tower fluid flow is effected by the suction of the cyclonic conversion tower.

9. A system according to claim 1 including a resilient cylinder situated at the end or bottom of the tower for throttling the fluid flow therethrough.

10. A system of multiple cyclonic and anticyclonic towers disposed in pairs - at least - in the predominant axes at the optimum distance of incidental flow disturbance such that suction is effected to the cyclonic tower from the anti-cyclonic tower forming a self-induced suction body, to which there may be added in the cyclonic tower, as

described in claims 1 and 5 a system for collecting thermal or solar radiant energy by means of conventional fuels.

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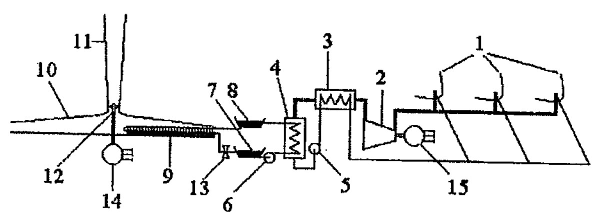
Die folgenden Angaben sind den vom Anmelder eingereichten Unterlagen entnommen

(54) Aufwindkraftwerk

(57) Die Erfindung betrifft ein Aufwindkraftwerk, das flächenspezifisch betrachtet eine hohe Energiemenge erzeugt und auch nachts mit hoher Leistung in betrieb bleibt. In Trockengebieten mit hoher Sonnenscheinintensität (Wüsten) ist diese Kraftwerk besonders interessant, da kein Kühlwasserverbrauch entsteht und hohe Temperaturschwankungen gut verwertet werden können.
Die Anordnung ist dadurch gekennzeichnet, daß das Aufwindkraftwerk mit einem unter dem Kollektordach (19) angeordneten Oberflächenkühler (9) mit Zu- und Rücklauf ausgestattet ist, der mit Warmwasser gespeist wird, das von einer außerhalb des Aufwindkraftwerkes gelegenen Wärme abgegebenen Einrichtung erwärmt wurde.
Als Wärmequelle wird vorzugsweise ein anderes solarthermisches Kraftwerk vorgesehen. Die Abwärme dieses anderen solarthermischen Kraftwerks, die vorwiegend am Kondensator (4) anfällt, erwärmt das aus einem Kaltwasserbecken (7) herangepumpte Wasser, um dieses in einem Warmwasserbecken (8) zu speichern. In den kühleren Nachtstunden fließt das erwärmte Wasser durch den unter dem Kollektordach (10) des Aufwindkraftwerkes angeordneten Oberflächenkühler (9) in das Kaltwasserbekken (7) zurück.



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Beschreibung

Die Erfindung betrifft ein Aufwindkraftwerk, das zusätzlich zu der Kollektorwärme auch die Wärme einer außerhalb dieses Kraftwerkes gelegenen Wärme abgebenden Einrichtung verwertet. Als Wärme abgebende Einrichtung ist vorzugsweise ein anderes solarthermisches Kraftwerk das neben Elektroenergie auch große Mengen Niedrigwärme abgibt vorzusehen. Die Erfindung macht die Verwertung dieser Abwärme im Aufwindkraftwerk, sowie den Wärmetransport und gegebenenfalls die Wärmespeicherung möglich, so daß die Abwärmeverwertung nachts erfolgen kann, wenn das Aufwindkraftwerk selbst nur mit geringer Leistung arbeiten würde. Solche Kraftwerksanlagen arbeiten ohne Wasserverbrauch, sie können daher in Trockengebieten betrieben werden.

Zur thermischen Stromerzeugung aus Sonnenenergie haben sich bisher folgende Großkraftwerke als geeignet erwiesen. Solarturm-, Solarrinnen- und Dish-Farm-Kraftwerke, die zusammen als solarthermische Dampfkraftwerke bezeichnet werden, Aufwindkraftwerke, Solarteichkraftwerke und Heißluftmaschinen, die durch Dish-Stirling-Systeme realisiert werden.

In Trockengebieten mit hoher Sonnenscheinintensität haben Aufwindkraftwerke den Vorteil, daß sie keine Kühlung brauchen. Ein weiterer Vorteil ist die Fähigkeit, Warmluft mit geringer Übertemperatur zur Außenluft in großen Mengen verarbeiten zu können und daher durch die Wärmespeicherung im Kollektorboden auch einen gewissen Teil Nachtstrom zu erzeugen. Nachteilig ist der durch diese Wärmespeicherung verursachte verzögerte Leistungsanstieg in den Morgenstunden und die geringe flächenbezogene Energieausbeute von Aufwindkraftwerken überhaupt. Mit 1000 m Kaminhöhe wird nur ca. 1% der auf den Kollektor einstrahlenden Sonnenenergie verstromt.

Andererseits ist bei der Nutzung solarthermischer Dampfkraftwerke in Trockengebieten die Kühlung problematisch. Solche Kraftwerke benötigen eine möglichst hohe Temperaturdifferenz zwischen dem warmen und dem kalten Wärmebehälter (Heißdampftemperatur – Kühlwassertemperatur). Weiterhin muß in Trockengebieten mit einem geschlossenen Kühlwasserkreislauf gearbeitet werden, denn für abfließendes Warmwasser bzw. Verdunstung steht kein Ersatz zur Verfügung.

Die Rückkühlung des Kühlwassers kann direkt oder mit Zwischenspeicherung erfolgen. Die direkte Kühlung hat den Vorteil, daß die zur Kühlung nötige Maschinenleistung (Pumpe, Ventilation) mit steigender Kraftwerksleistung ansteigt und deshalb direkt dem Kraftwerk entnommen werden kann. Nachteilig ist, daß die hohe Kühllufttemperatur bei intensiver Sonneneinstrahlung hohe Ventilationsleistung erfordert und daß der thermische Wirkungsgrad sinkt. Dadurch sinkt der Gesamtwirkungsgrad des Kraftwerkes beträchtlich. Bei Kühlung mit Zwischenspeicherung erfolgt die Rückkühlung des Kühlwassers nachts, indem das Kühlwasser von dem warmen Becken durch den Kühler in das kalte Becken transportiert wird. Die Kühlluft ist dann wesentlich kälter. Tagsüber nimmt das Kühlwasser die Kondensationswärme auf. Der thermische Wirkungsgrad steigt auf Werte, die vom Kraftwerk mit offener Naßkühlung bekannt sind und es ist weniger Ventilationsleistung erforderlich. Diese wird aber zu einer Zeit, nämlich nachts, verlangt, zu dem Solarenergie nicht direkt erzeugt werden kann. Es müßte Fremdenergie zugeführt, auf Brennstoffbetrieb umgestellt oder aufwendige Energiespeicherung eingebaut werden.

Heißluftmaschinen werden gegenwärtig durch Dish-Stirling-Systeme realisiert. Bei den bisher erstellten Kleinanlagen begnügt man sich mit Luftkühlung auf der Schattenseite des Spiegels.

Bei größeren Anlagen mit optimiertem Wirkungsgrad sind ähnliche Kühlprobleme zu erwarten, wie bei den solarthermischen Dampfkraftwerken.

Die bisher realisierten Solarteichkraftwerke arbeiten alle mit Verdunstungskühlung an der Teichoberfläche. Dabei entsteht Wasserverlust, der sie für Trockengebiete ungeeignet macht. Der Wirkungsgrad liegt mit 1 . . .2% noch sehr niedrig, so daß die Solarteiche ähnlich groß sein müssen, wie die Kollektordächer von Aufwindkraftwerken. Durch die große Wärmekapazität der Solarteiche tritt die Spitzenlastfähigkeit von Solarteichkraftwerken hervor.

Die Aufgabe der Erfindung besteht darin, Trockengebiete mit hoher Sonnenscheinintensität für die Energieerzeugung im großen Maßstab nutzbar zu machen. Dabei soll die auf die Grundfläche bezogene Leistungsdichte sehr hoch sein und die Stromgestehungskosten niedriger als bei den derzeitigen solarthermischen Kraftwerken, wenn diese ohne offene Naßkühlung betrieben werden müssen. Außerdem soll der hohe Grad der Bodenversiegelung, wie diese durch die Kollektordächer in Parks von Aufwindkraftwerken realisiert wird, eingeschränkt werden.

Erfindungsgemäß wird diese Aufgabe dadurch gelöst, daß das Aufwindkraftwerk mit einem unter dem Kollektordach angeordneten Wasserröhrensystem mit Zu- und Rücklauf, das als Oberflächenkühler wirksam werden kann, ausgestattet wird. Dabei werden Zu- und Rücklauf mit einer Wärme abgebenden und in das Wasser eintragenden Einrichtung verbunden. Vorzugsweise tritt an die Stelle der Wärme abgebenden Einrichtung ein anderes solarthermisches Kraftwerk, das die eingefangene Sonnenwärme nur teilweise verstromen kann und größere Mengen Niedrigwärme abgibt. Da sich der Oberflächenkühler bei Sonneneinstrahlung auf das Kollektordach mit erwärmt, kann er seiner eigentlichen Kühlaufgabe nur nachts gerecht werden. Außerdem erhält der Aufwindkamin bei intensiver Sonneneinstrahlung genügend Auftrieb durch die Kollektorwärme. Daher muß das außerhalb des Aufwindkraftwerkes gelegene solarthermische Kraftwerk mit Einrichtungen ausgestattet sein, die die Abgabe von Warmwasser an den Oberflächenkühler in der Nacht ermöglichen.

Nach Anspruch 2 ist als Wärme abgebende Einrichtung ein Solarrinnen- oder Solarturmkraftwerk vorgesehen. Diese Kraftwerke haben selbst nur geringes Wärmespeichervermögen. Deshalb wird bei diesen Kraftwerken ein Kalt- und ein Warmwasserbecken für das Kühlwasser angeordnet. Am Tage wird aus dem Kaltwasserbecken das Kühlwasser für das Solarrinnen- bzw. Solarturmkraftwerk entnommen, es erwärmt sich im Kondensator und wird im Warmwasserbecken gespeichert. Nachts fließt das Warmwasser durch den Oberflächenkühler des Aufwindkraftwerkes, wo es sich nahezu auf die Temperatur der Außenluft abkühlt, in das Kaltwasserbecken zurück. Dabei erwärmt sich die Luft unter dem Kollektordach und der Kaminauftrieb bleibt nachts erhalten, so daß das Aufwindkraftwerk mit hoher Nachtleistung in Betrieb bleibt. Außerdem gewährleistet der Kaminauftrieb die Ventilation am Oberflächenkühler.

Aufwindkraftwerke mit einem Oberflächenkühler nach Anspruch 1 erzeugen, durch die hohe Nachtleistung bedingt, erheblich mehr Energie, als Aufwindkraftwerke ohne Oberflächenkühler. Weiterhin steigt in dem als Wärme abgebende Einrichtung genutzten solarthermischen Kraftwerk der thermische Wirkungsgrad, da in der Nacht gekühltes Kühlwasser zur Verfügung steht und es wird die Ventilationsleistung für die Kühlung eingespart.

Nach Anspruch 3 werden als Wärme abgebende Einrichtung Heißluftmaschinen vorgesehen. Bei Maschinen mit ge-

schlossenem Luftkreislauf fällt die Wärme bei der Rückkühlung der Luft an. Durch Anwendung von Wasserkühlung wird die Wärme in das Kühlwasser eingetragen. Maschinen mit offenen Luftkreislauf geben ihre Abwärme mit der Abluft ab. Diese Warme kann mit Wärmetauschern in das Wasser eingetragen werden. Da Heißluftmaschinen keine Wärme speichern können, müssen Kühlwasserzulauf und Kühlwasserrücklauf mit Speicherbecken ausgestattet werden.

Besonders günstige Eigenschaften werden erlangt, wenn als Wärme abgebende Einrichtung Solarteiche oder Solarteichkraftwerke nach Anspruch 4 vorgesehen werden. Solarteiche verfügen selbst über eine erhebliche Wärmespeicherung, so daß Speicherbecken für das Kühlwasser nicht unbedingt erforderlich sind. Die nächtliche Wärmeabgabe des Teiches wird durch geeignete Schichtung des Salzgehaltes im Teichwasser minimiert. Um Verdunstungsverluste von Teichwasser zu vermeiden, ist der Teich durchsichtig abzudecken. Die Verdunstungskühlung der Teichoberfläche kann entfallen, weil die Abwärmeabführung zum Aufwindkraftwerk erfolgt und nicht an die Teichoberfläche.

Die einfachste Nutzungsart beruht darauf, daß immer dann, wenn das Aufwindkraftwerk nicht selbst mit seiner Höchstleistung arbeitet, dessen Leistung durch Zufuhr von warmen Teichwasser in den Oberflächenkühler gesteigert werden kann. Der Rücklauf mündet wieder in den Solarteich. Der Zeitraum für die Leistungssteigerung ist frei wählbar, die Höhe der Leistungssteigerung aber durch den Aufwind-Maschinensatz begrenzt.

Ein noch stärker auf die Nachtstunden orientiertes Leistungsangebot ergibt sich, wenn ein Solarteichkraftwerk ohne Kühlwasserspeicherbecken als Wärme abgebende Einrichtung betrieben wird. Am Tage kann die Abwärme des Solarteichkraftwerkes nicht ausreichend abgeführt werden, deshalb kann es nicht arbeiten. Nachts kann das Aufwindkraftwerk die Abwärme übernehmen, so daß beide Kraftwerke mit hoher Leistung arbeiten können.

Sind aber Speicherbecken für das Kühlwasser vorhanden, so kann das Solarteichkraftwerk wahlfrei arbeiten, also sowohl Grund-, Mittel,- als auch Spitzenlaststrom erzeugen.

Für die Verarbeitung von eingetragener Wärme sind Aufwindkraftwerke mit hohen Kaminen und relativ kleinen Kollektoren zu bevorzugen, da die Effektivität der Wärmeverwertung mit der Kaminhöhe steigt und die Transportwege des Wassers als Wärmeträger nicht unnötig verlängert werden sollen.

Die Erfindung soll nachfolgend anhand eines Ausführungsbeispiels erläutert werden. Die zugehörigen Zeichnungen zeigen:

Fig. 1 zeigt den prinzipiellen Aufbau eines Aufwindkraftwerkes, in das die Abwärme eines Solarrinnenkraftwerkes eingetragen wird.

Fig. 2 zeigt den Grundriß einer solchen Anordnung.

In **Fig.** 1 sind Solarrinnen **1** mit Direktverdampfung in den Absorberrohren dargestellt. Der Dampf entspannt sich in der Dampfturbine **2**, die den Generator **15** treibt. Ein Teil der Abdampfwärme wird im Vorheizer **3** an das Speisewasser übertragen. Die restliche Abdampf- und Kondensationswärme wird im Kondensator **4** an das Kühlwasser übertragen, wobei der Dampf selbst kondensiert. Die Kesselspeisepumpe **5** pumpt das Kondensat über den Vorheizer zu den Absorberrohren zurück.

Die Kühlwasserpumpe **6** pumpt das Kühlwasser aus dem Kaltwasser-Speicherbecken **7** durch den Kondensator. Dabei erwärmt sich das Kühlwasser und es gelangt in das Warmwasser-Speicherbecken **8**. Dort wird es tagsüber gespeichert. Nachts wird das Ventil **13** geöffnet damit das warme Speicherwasser durch den unter dem Kollektordach **10** angeordneten Oberflächenkühler **9** in das tiefer gelegene Kaltwasser-Speicherbecken **7** zurückfließt. Dabei entsteht Warmluft unter dem Kollektordach, die auch nachts den Auftrieb im Kamin **11** aufrecht erhält und die Aufwindturbine **12** mit hoher Leistung antreibt, so daß der Generator **14** große Mengen Nachtstrom liefert.

In **Fig.** 2 ist der Grundriß einer ausgeführten Kraftwerksanlage auf 4 km × 4 km Gesamtfläche dargestellt. Kollektorradius und Kaminhöhe betragen ca. je 1000 m. Durch die kompakte Anordnung der Kraftwerke werden kurze Rohre für den Transport des Speicherwassers realisiert. Solarrinnenfelder, Speicherbecken und Kollektordach sind maßstabstreu dargestellt. Die Speicherbecken sind ca. 5 m tief. Im Maschinenhaus **16** sind Dampfturbine, Generator, Kondensator, Vorheizer und Pumpen untergebracht. Die elektrische Pikleistung liegt bei 30 MW aufwindseitig und bei 4 × 150 MW solarrinnenseitig.

Patentansprüche

1. Aufwindkraftwerk, bestehend aus einem Kamin **(11)** dessen Fuß von einem schirmförmigen Kollektordach **(10)** umgeben ist und der die Luftströmung vom scheibenförmigen Ringraum unter dem Kollektordach zum Kamin freigibt, sowie mindestens einer in dieser Luftströmung angeordneten Windturbine **(12)**, **dadurch gekennzeichnet**, daß ein unter dem Kollektordach angeordnetes Wasserröhrensystem **(9)**, das als Oberflächenkühler wirksam werden kann, mit mindestens je einem Zu- und Rücklauf für das Wasser als Wärmeträger ausgestattet ist, wobei Zu- und Rücklauf mit einer Wärme abgebenden und in das Wasser eintragenden Einrichtung verbunden sind.
2. Aufwindkraftwerk nach Anspruch 1, dadurch gekennzeichnet, daß als Wärme abgebende Einrichtung ein Parabolrinnen-, Solarturm- oder Dish-Farm-Kraftwerk vorgesehen ist, wobei zum Wärmeeintrag die am Kondensator eines solchen solarthermischen Dampfkraftwerkes anfallende Abwärme genutzt wird und im Zu- und Rücklauf für das Kühlwasser Zwischenspeicherbecken angeordnet sind.
3. Aufwindkraftwerk nach Anspruch 1, dadurch gekennzeichnet, daß als Wärme abgebende Einrichtung solarthermische Heißluftmaschinen mit offenem oder geschlossenem Luftkreislauf vorgesehen sind, wobei Wasserkühler die Abluftwärme bzw. die Rückkühlwärme der Heißluft in das Wasser eintragen und im Zu- und Rücklauf für das Kühlwasser Zwischenspeicherbecken angeordnet sind.
4. Aufwindkraftwerk nach Anspruch 1, dadurch gekennzeichnet, daß als Wärme abgebende Einrichtung Solarteiche und/oder Solarteichkraftwerke vorgesehen sind, wobei zum Wärmeeintrag die fühlbare Wärme des Teichwassers bzw. die am Kondensator eines Solarteichkraftwerkes anfallende Abwärme genutzt wird.

Hierzu 2 Seite(n) Zeichnungen

- Leerseite -

ZEICHNUNGEN SEITE 1

Nummer: DE 198 21 659 A1
Int. Cl.[6]: F 03 D 9/00
Offenlegungstag: 18. November 1999

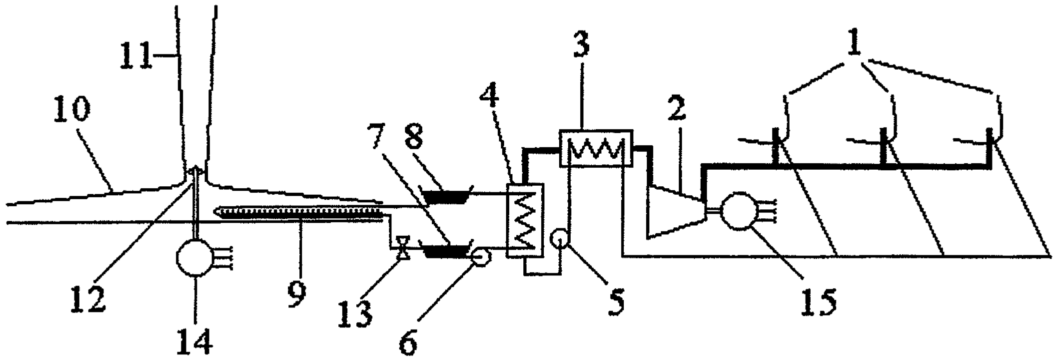

Fig. 1

ZEICHNUNGEN SEITE 2

Nummer: DE 198 21 659 A1
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Offenlegungstag: 18. November 1999

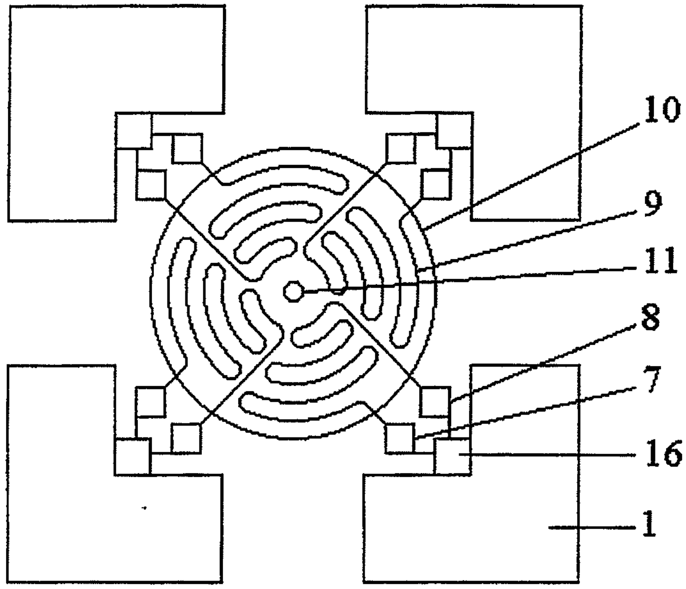

Fig. 2

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(51) INT CL[5]
F03G 6/04

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F1N NX
U1S S1903 S1960

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US 4876349 A US 4359870 A

(58) Field of search
UK CL (Edition L) F1N NX
INT CL[5] F03D, F03G
Online database: WPI

(54) **Air flow generating apparatus**

(57) Apparatus for generating an air flow comprising a duct 1 (which could be in the form of a tower) which rises to a substantial height, e.g. 10 to 17 km. Means are provided for providing warm air for passage up the duct, which may include the provision of a large transparent roof over the ground surrounding the duct to heat the air beneath the roof by solar heating. For this purpose the roof may include water-filled solar panels connected to the heat exchangers 5. The warm air in the duct rises to a height at which moisture may condense therefrom thus creating a further driving force for the air flow through the duct. The air flow into the duct through inlets 4 and the exchangers 5 may be used to drive turbines 6 for the generation of electricity. Further air inlets 7 are provided in the side of the tower. The apparatus simulates hurricanes by the removal of solar heat from the ground and the transport of this heat to a high altitude. The removal of ground solar heating in an area prone to hurricanes may thus prevent natural hurricanes occurring.

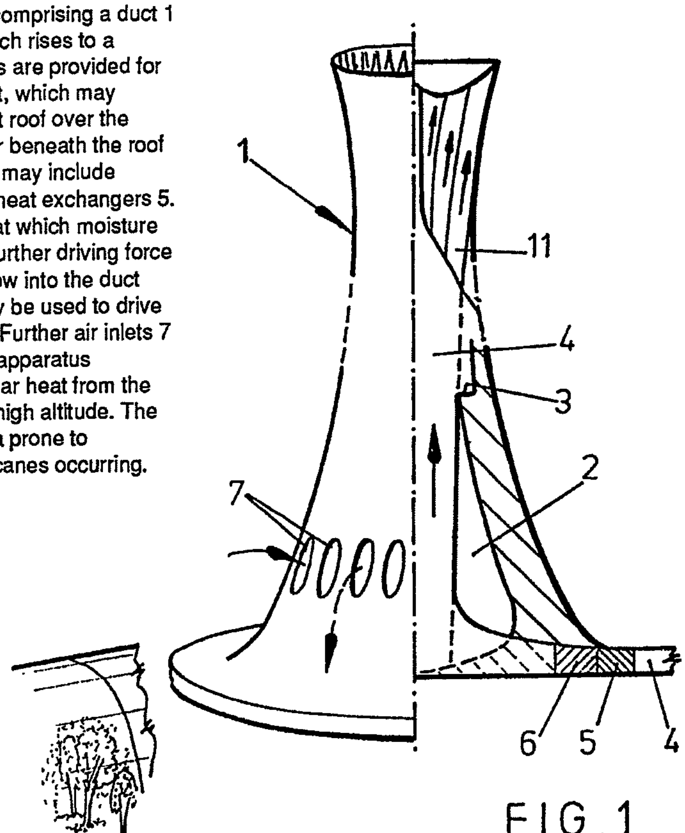

FIG. 1

GB 2 261 705 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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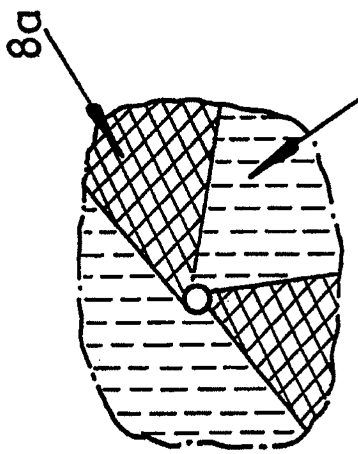
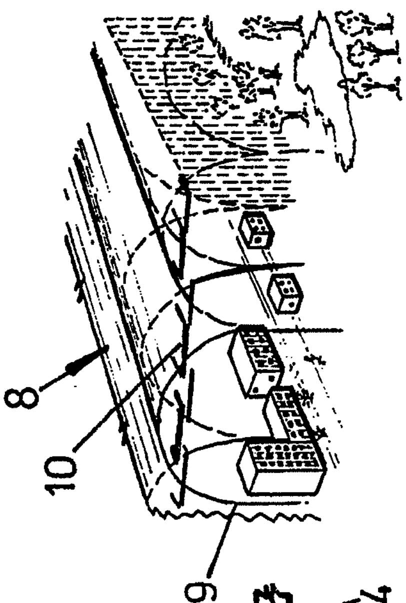


FIG. 2



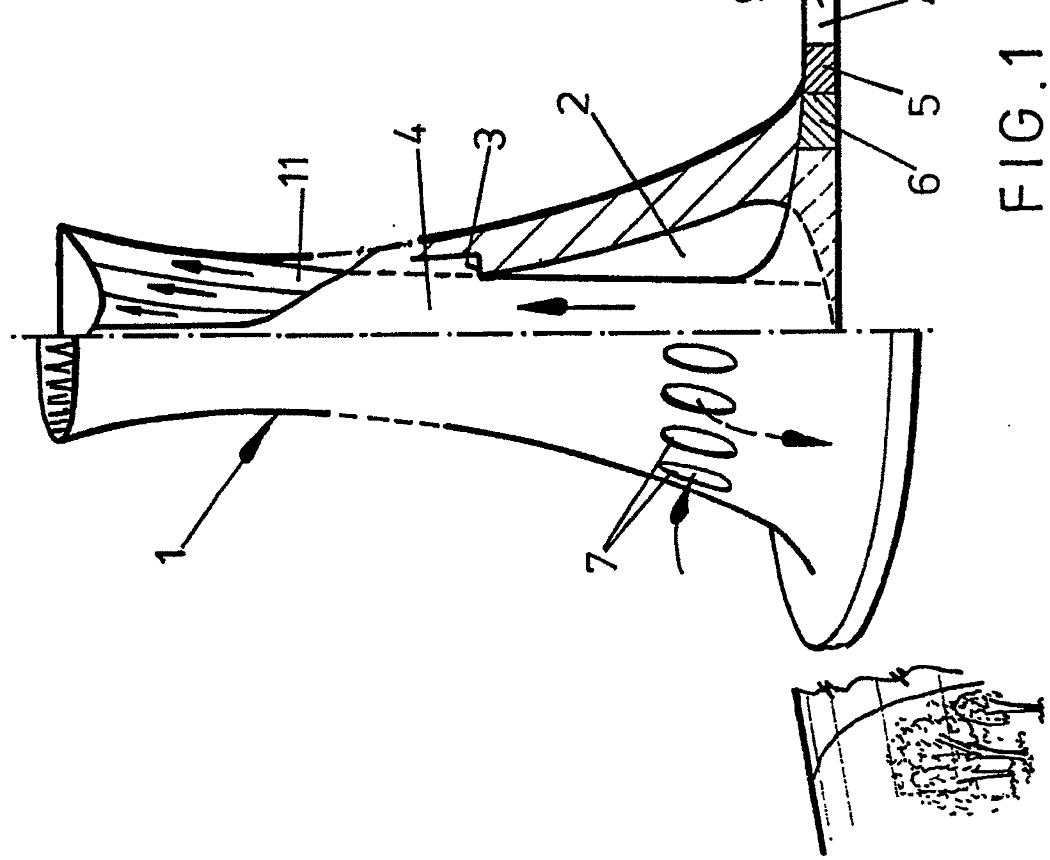


FIG. 1

15 12 92

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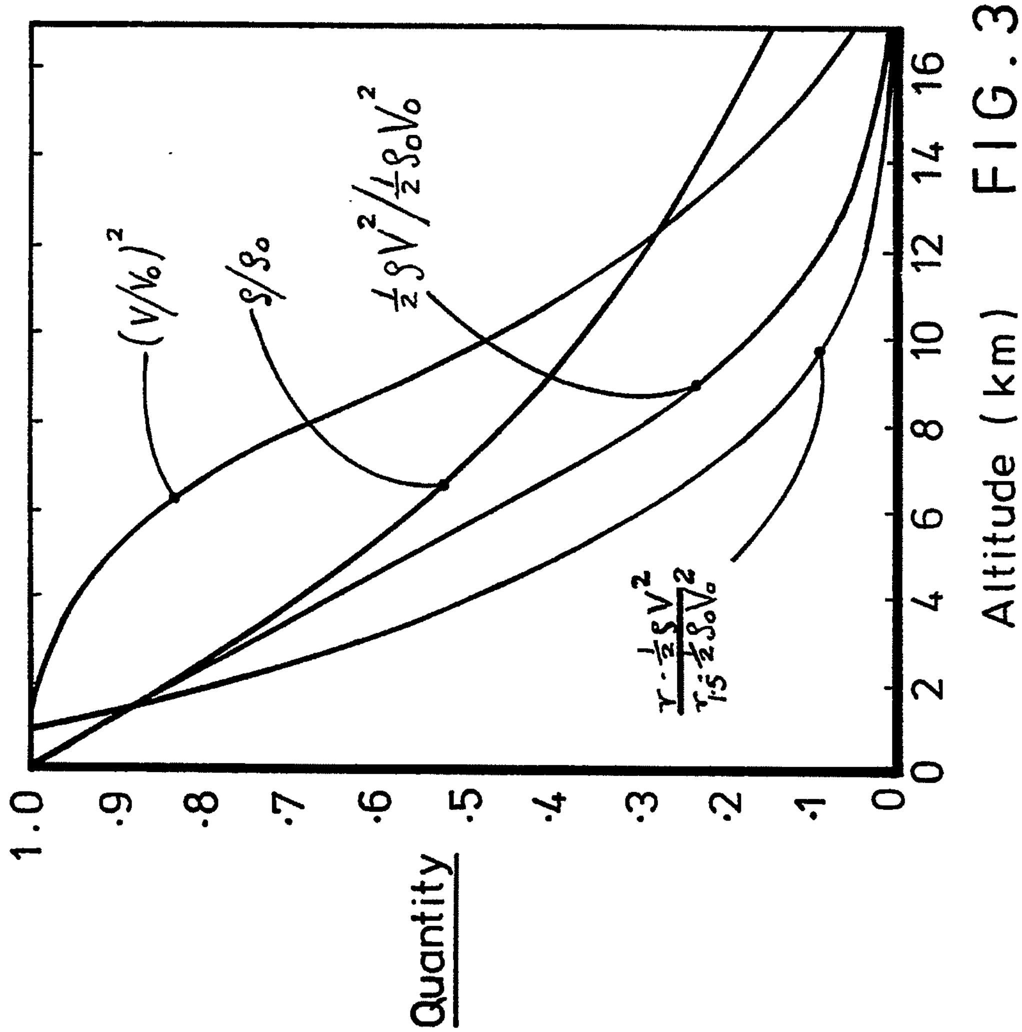

FIG. 3

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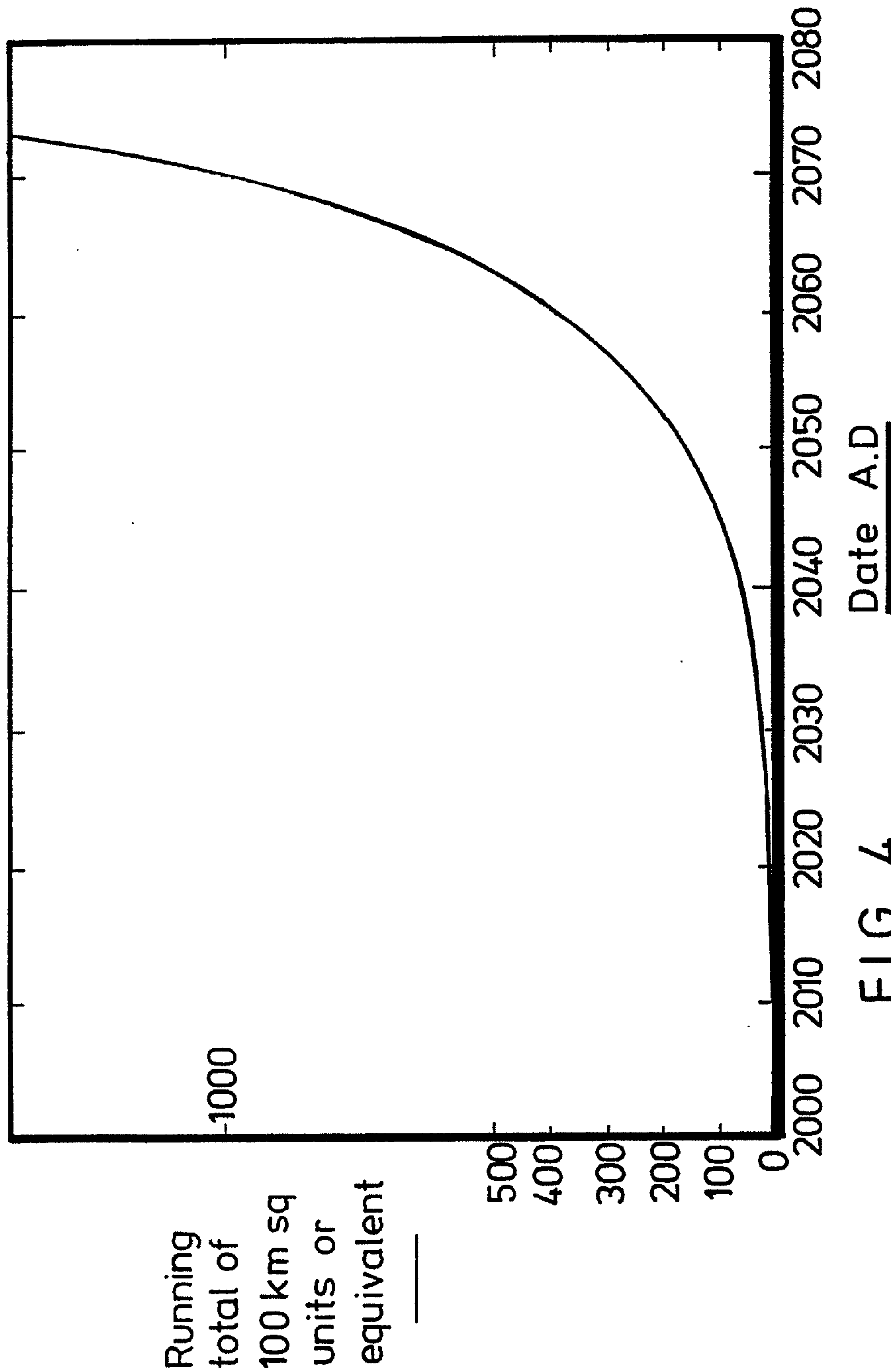

FIG. 4

APPARATUS FOR GENERATING AN AIR FLOW

The present invention relates to the generation of an air flow, and more particularly to the generation of such a flow which simulates some of the conditions within a hurricane. The air flow may be used, for example, in the generation of electricity or the production of fresh water.

A hurricane is centred around a low pressure region. Warm, moist air is drawn from ground level and spirals upwardly around the low pressure region. As the air rises to higher altitude, it is cooled by expansion due to the lower pressures encountered at these altitudes resulting in precipitation of rain with a consequential component of warming of the air due to the latent heat of condensation of the water.

Emanuel (1986) has shown that the Carnot efficiency of hurricanes is about a third, as a result of most of the heat being added at the sea surface at about 300°A and removed at high altitude at little more than 200°A. In principle, this hurricane cycle could be utilised for the generation of electricity and fresh water. However, the occurrence of a hurricane is difficult to predict, and because a hurricane moves, it is not practical to site generating apparatus inside the high velocity regions of the hurricane.

According to a first aspect of the present invention there is provided an apparatus for generating an air flow comprising a duct rising to a substantial height and means for providing warm air for passage up the duct, the duct being such that the warm air rises in the duct to a height at which moisture could condense out of the air to cause a further driving force for an air flow through the duct.

In accordance with the invention, the height of the duct is such that, if a moderate or large amount of moisture is present in the air rising in the duct, the moisture is able to condense out of the air during rising, thus releasing the latent heat of the moisture into the air. This release of heat into the air causes the temperature of the air to increase relative to the situation without condensation, thus providing the further driving force indicated above for the air flow through the duct. However, a duct of such a height provides, also, another mechanism by which a further driving force for an air flow through the duct is generated. In such a duct containing warm low density air, the weight of the upper air acting on the air at intermediate levels in the duct will be less than the weight of upper air acting on intermediate level air outside the duct. Thus less pressure will be acting on the air at intermediate level in the duct, so that this air at intermediate levels will be of reduced density, not only because of its temperature, but also because of its pressure. Consequently, there is a further reduction of pressure acting on the air in the base of the duct, and therefore a further driving force for air flow through the duct. This second, further mechanism – or magnification effect – can be significant in ducts of substantial height. It does not rely on moisture being present in the

warm air fed to the duct: moisture influences the amount of magnification, but the height of the duct is sufficient to provide some magnification of the driving force with dry air, provided that the air remains warmer than outside the duct even at the upper altitudes of the duct. The present invention, because of the relatively high thermodynamic efficiencies potentially attainable for all reasons, is concerned broadly both with the fundamentals of such ducts of substantial height, and with practicable ways in which such ducts might be designed and operated, for all likely levels of moisture content. The schemes mentioned first have problems particularly of scale. However, the concepts are broadened in some of the subsequent schemes in order to allow a smaller and more immediately practicable scale and greater flexibility.

In one advantageous embodiment of the invention, the duct is surrounded by a substantial area provided with a flat, transparent roof from beneath which the air is supplied to the duct. The air beneath the flat, transparent roof may be moistened by a spray of water taken from the condensate in the duct. Further water may be heated by solar panels situated beneath a part of the transparent roof. This water may be used directly or indirectly, both for heating and for moistening the air, possibly after storage.

The duct may be in the form of a tower. The tower may be between 5 and 20 km high, and the transparent roof may cover an area of the order of 100 km square. The diameter of the base of the tower may be approximately 12 km, and the diameter of the top of the tower may be approximately 5 km.

The tower may be provided with internal ducting, which may be configured in helices, or have swirl. The tower may also have air inlets at a height of between 2 and 4 km. Air may be drawn into these air inlets and then circulated to part of the area under the transparent roof. This air may be cooled by water spray, using the water that has condensed out of the rising warm moist air.

The duct may be provided with buoyancy compartments so that it is partly or entirely self-supporting. The buoyancy compartments may be analogous to balloons or airships.

The duct may be in the form of a wind sock. The sock may be inclined at an angle to the horizontal of 20°. The sock may have outer annuli of helium and air at a slightly increased pressure, to provide buoyancy. The sock may have internal tensioning members in order to maintain its circular cross-section. The sock may be able to rotate about one end in order that the longitudinal axis of the sock may lie along the direction of the prevalent wind. The sock may also be able to rotate along its longitudinal axis to allow clearance of any ice or snow deposits on the sock.

The sock may be formed with one or more concertina type sections, to allow the sock to bend to follow changes of wind direction with altitude. The internal diameter of the sock at ground level may be 0.3km.

The duct may be positioned adjacent to a mountain face, and may thus be supported

along its length. The duct may be partly formed from the mountain. A tower or sock arrangement may be provided at the top of the duct.

Electricity generating means may be situated at the base of the duct, which may be provided with turbines. The turbines are driven by air sucked into the duct by the pressure drop in the duct when the warm moist air rises. Heat exchangers may be situated at the base of the duct, to heat further the warm moist air before it is used to drive the turbines. The heat exchangers could employ water heated in the solar panels provided under the transparent roofed area.

The duct may be sited over land or over water. If the duct is situated over water it may be supported by a platform which may be a floating platform.

According to a second aspect of the present invention there is provided an apparatus for generating an air flow comprising means for generating an air vortex rising to a substantial height, and means for providing warm air for passage up the vortex, the vortex extending to such a height that the warm air rises in the vortex to a height at which moisture could condense out of the air to cause a further driving force for an air flow through the vortex.

It will be appreciated that the apparatus of the present invention could be used for the production of electricity and fresh water. The generation of electricity could be more economic, and cleaner than present power generation. Further, the removal of solar heating and stored heat over a significant area of land or ocean surrounding the duct (i.e. by means of solar panels and/or air flow beneath a roofed enclosure) would reduce the convective tendencies of air passing over those areas and could reduce the tendency for this air to form hurricanes naturally.

Specific embodiments of the present invention will now be described by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic illustration of an apparatus according to the present invention;

Figure 2 is a schematic diagram showing a distribution of solar panelled areas around the apparatus of Fig. 1;

Figure 3 is a schematic diagram of the variation of hurricane windspeed and other wind loading parameters with altitude; and

Figure 4 is a schematic diagram of the possible rate of building of the apparatus of Fig. 1.

Referring to Fig. 1 there is schematically illustrated a tower 1 which is of substantial height, typically rising to an altitude of approximately 10 to 17 km (this is similar to the average heights of naturally occurring hurricanes).

The diameter of the tower 1 would be approximately 5 km at the top, and 12 km at the base. The tower 1 would be constructed mainly from structural steel, and would have interior ducting 2 to carry rising air to the top of the tower. The ducting 2 would provide

a helical flow path. The ducting may be expanded at one or more levels 3. Air inlets 4 are provided at the base of the tower 1, to enable air to be drawn into the tower near ground level. Heat exchangers 5 and turbines 6 are provided near the base of the tower 1, connected to the air inlets 4. Further air inlets 7 are provided in the tower at a height of between 2 – 4 km.

Surrounding the tower is an area of approximately 100 km square covered with an essentially flat transparent roof 8 at a height of approximately 100m. The transparent roof 8 would be supported on a framework 9 of light structural steel formed into inverted catenary arches, with the transparent panelling in slightly domed plastic of approximately 1 mm thick. A part 8a of the area covered by the roof is provided with high – level solar panels 10, to heat water in the panels, and to shield the area directly below the solar panels from the sun's radiation. A part 8b of the area covered by the roof could be used for living areas or cultivation..

The tower and roof structure could be built in a region that is a site for the formation of hurricane embryos, an example of such a region being the coastal area of West Africa.

In use, water is heated in the solar panels 10 provided under part of the transparent roof area 8. This heated water is then used, possibly after storage, to heat and moisten the air passed from under the remainder of the roof 8 in the heat exchangers 5. This air would already have received direct solar heating, mainly as it passed under the part of the transparent roof without solar panels, and it would have been moistened by spraying some of the water from the tower into the roofed area and allowing it to fall under the influence of gravity, in a similar manner to rain. The warm, moist air within the enclosure 8 is drawn into the base of the tower 1, through the heat exchangers 5 and turbines 6.

As the air rises in the tower, its temperature decreases, thus causing condensation. This condensation of the water from the air causes the temperature of the air to rise, compared to the ambient air outside the tower, and compared to a situation with no condensation, due to the release of latent heat. The warm air rises because it is less dense than cool air, and there is less pressure acting on the air in the tower than on the ambient air surrounding the tower. The lowering in pressure of the air in the tower depends on the height of the tower – the higher the tower is (within the troposphere), the greater is the height of warm air contained in it, and consequently (because the warm air is less dense than the ambient air) the lower is the pressure in the tower.

The air rising in the tower sucks more air into the base of the tower from the surrounding area. The force of this wind being sucked into the tower is used to drive the turbines, and can thus be harnessed to generate electricity. The water that condenses out of the rising air falls against the walls of the main ducting inside the tower, and is collected by supplementary ducting in the tower. This water can then be used to irrigate the surrounding

areas, as fresh water for the population, recycled as necessary, and for the solar panels provided in the roofed areas. Icing of the walls of the tower is prevented by the expansion of the ducting, in order to prevent freezing rain reaching the walls.

Air is also drawn into the tower 1 through the air inlets 7 situated at a height of between 2 and 4 km. This air is drier than air at ground level. Consequently it can be brought down to the base of the tower by being cooled on its way down by water spray, using the water that has been condensed out of the rising, warm moist air. This cool air from the air inlets 7 is circulated at low level to the part 8a of the roof. The part 8a may have an urban conurbation built within it and the cool air would provide people living within the urban conurbation with a cool artificial climate.

In another embodiment of the present invention, a tower and either a roofed area or a compact ocean-to-air heat exchanger are provided on a platform over the ocean. The platform may either be fixed, in a similar manner to oil rigs, or may be provided on a mobile floating platform, to enable the platform to be moved away from high winds, to precede a hurricane to provide cooling, to extract heat from a particularly favourable warm area of ocean, or to cause the ocean water to pass through the heat exchanger. The ocean-to-air heat exchanger would use vortex generators in the form of cyclically twisted aerofoils, these vortex generators ensuring the compactness of the heat exchanger. The vortex generators may be used compounded to produce vortices within vortices. The floating platform and other aspects of the invention could be used in temperate regions.

In temperate regions the tower could rise to an altitude of 5 to 10 km, because of the lower tropopause and lower jet streams in temperate regions.

In a further embodiment of the invention, arrangements are made to allow the concertina sock type of duct to be "wound in" and stowed prior to rare winds of extremely high intensity.

Further details of the technical aspects of the present invention are described in Appendix I. The concepts behind the present invention, and further embodiments, are discussed in Appendix II. In most of Appendix I, the situation corresponds to that of Fig. 1. In Appendix II, the broader concepts are introduced in order to allow the smaller scale of application and greater flexibility.

<u>Reference</u>

Emanuel, K. A., 1986: An air-sea interaction theory for tropical cyclones. Pat I: Steady-state maintenance. <u>J. Atmos. Sci.</u>, <u>43</u>, 585-604.

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APPENDIX I

Further Details of the Technical Aspects of the Present Invention

Most of this Appendix I is concerned with the type of situation shown in Fig. 1. That situation is regarded as perhaps the most fundamental, so that a considerable amount of detail is discussed. However, there are considerable problems in the Fig. 1 type situation - particularly of scale. Consequently in Appendix II other, broader, concepts will be introduced.

a. The transparent roof

A transparent roof is used for capturing the sun's heating and controlling the air flow.

The roof is nearly flat and is essentially aerodynamically continuous in all directions. It therefore eliminates substantially all of the wind loads as far as these are related to the geometry of the roof. In addition, the air of the system enters through intakes which are essentially just holes in the roof, suitably placed. Consequently the dynamic head in the air as a result of the wind is dissipated under the roof without causing any pressure rise - again eliminating the potential pressure load on the roof. Furthermore, in all the outer parts of the roofed area the air velocities through the intakes and under the roof are kept fairly low in order to keep down the corresponding pressure losses and again avoid loading on the roof. Consequently the total wind loads and air loads on the roof are substantially zero and a very light weight roof is possible.

The main part of the structure supporting the roof, as at present envisaged, is superficially like the ceiling vaults of a gothic cathedral. However, the structure of the flat roof itself converts the apparent arches of the "ceiling" into tapered cantilevers of very high depth to length ratio. These carry near zero load. The columns and vaults are therefore thought of as extremely light sections, in steel with suitable protection, for a pitching of the columns in both directions of say 100 metres and for a roof height of about 100 metres. The transparency of the roof is provided by panels based on domed sheets of rigid plastic, 1 mm thick. The domed panels on a local scale are contrary to the flatness of the roof. However, subject to further work, it seems to be possible to provide domes of height equal to about 5 to 10% of their diameter without causing excessive pressures from the wind. The air intakes may perhaps be arranged at some suitable mean radius within each of the panels in order to keep down the air pressure loading.

The above transparent roof is not intended to withstand the inherent field of static pressure of a developed tornado or hurricane. In order that these should only very rarely occur over a system unit with transparent roofs, in each hurricane region the units would be built starting from the windward outer edges, in positions somewhat upwind of where most of the hurricanes begin. However, for the occasion when a tornado or hurricane does cross a transparent roof, the static pressure field would be pressure balanced across the roof by having a proportion of the roof, perhaps 10%, probably in thin flexible plastic sheet which is able to burst without causing injury, or, just possibly, in some form of automatic windows which are able to go to an open position and still keep low drag. The small scale of a tornado could still cause failure of some of the ordinary roof panels but, subject to further study, the resulting air flow from under the roof could cause the core to "fill" before doing very much damage.

Trees and buildings under the transparent roof are grouped suitably in order to keep down the pressure losses in the air flow. Some of the incoming sun's heat is collected in

solar hot water panels and carried by the water, both to supply the storage and to keep down the demands on the air flow. The main areas for living and working would be supplied with the cooling air brought down from altitude by a moisture induced cool downdraught in the tower.

The heat transfer rate through the single skin roof would be very small per unit area partly because the external air would be insulated from moisture pick-up and would tend to increase in temperature by mixing with the air from higher altitudes, and partly because the internal air would rise in temperature only a fairly small amount because of its high moisture pick-up. However, because of the very large area of the roof the heat loss through a single skin might still be significant. Consequently, some parts, at least, may have a second skin formed perhaps from the "ceiling vault". The space between the roof and ceiling would be ventilated by suitably arranging the flow paths of the air entering the system. The heat would then be retained within the air flow.

The low cost transparent roof that has been discussed above would be used particularly for the central parts of a unit. The outer parts of the units may be based on conventional low cost greenhouse buildings and may collect some heat from surrounding areas by suitable cropping, water spray and air flow intakes. These arrangements could discourage thermals and allow the accumulated heat to pass into the system.

b. **The tower**

The tower 1 in Fig. 1 is constructed in two parts. The upper part, above 1½ km, is constructed mainly in structural steel, suitably protected against both corrosion and low temperature brittleness - the latter probably by insulation and space heating; the lower part is constructed in reinforced concrete. Both parts are strongly tapered in their structure, rather after the established method of the "Eiffel Tower". The tower may advantageously be built on high ground if low ground for the transparent roof 8 is available close by.

In the tower the air flow first rises to a height of 7 to 8 km, possibly through 32 tubes 2. These would run in combined spirals and helices in both directions close to the outer perimeter wall. They would be joined to the wall by webs, both for local stiffening of the wall, and for transmission of the wind loading circumferentially and downwards. At between 7 and 8 km altitude the 32 tubes lead into a central chamber 12, which reaches to 12 km altitude. The air cools through 0°C in the lower part of this chamber and in that region the walls are stepped outwards at a sudden expansion 3 in order to avoid ice formation on the tube walls. The top part of the tower again has 32 tubes 11 each in the form of a helix. In the helices the tubes are at about 20° to 30° inclination to the vertical, in order that the rain and the combined particles of hail and snow can fall to the lower surface of the tubes and be collected by gutters and then through ports. The ports may include "U-bends" in order to allow the liquid-like mass to be removed without leakage of air from the pressure drop across the tube walls. If sufficient of the snow does not link itself to the hail it could be necessary to inject additional water into the 11 to 12 km region, as a sort of wash, as light weight snow would be difficult to collect. The surfaces above 8 km may be kept a very small amount warmer than the local air flow in order to encourage slow regulation of any adhering particles. The whole of the method for the removal and collection of the hail and snow would probably require considerable study in order to obtain a reasonably efficient yield while avoiding icing problems. The removal of the precipitation is important for the air flow efficiency, also, particularly at high altitudes, in order to keep down the effective air flow density. An increase in effective density at high altitude increases the pressure and therefore the density at all lower altitudes and, therefore, gives a magnified increase in pressure at the turbine outlet. (The positive aspect of this argument, well known in meteorology, explains

why only a small temperature differential at very high altitude is required to give a relatively large pressure drop at surface altitude, both in hurricanes and in the present proposals.) A compromise is desirable at the freezing altitude because of the latent heat released as the rain freezes.

An alternative to the above arrangement is that the helical tubes 2 below 7 to 8 km may be replaced by a single central tube, with helical fins to give swirling flow to separate out and collect the rain. The "step" 3 at 7 to 8 km would still be used for avoiding icing. Intermittent radiation may be used in either arrangement for small amounts of de-icing at any altitude. Insulation would be used as appropriate.

In order to examine the wind loading on the tower, as a first step, various components of a wind loading are assessed in the form of non-dimensional altitude distributions. The velocities used in Fig. 3 are from the contours for Hurricane Inez, taken from Hawkins and Imbembo's analysis of 1976, for when the measured central pressure was 927 mb. The nominal surface velocity taken from the contours is 135 knots, i.e. 68 m/s, as derived mainly from the lowest altitude flight measurements which, in that region, were made at a true height of about 1 km and therefore above the surface boundary layer. The densities used in Fig. 3 are from Jordan, 1958. The drag coefficient for the tower has been taken to be uniform at a value of unity, while the radius is from a sketch of the tower, after iteration.

The above wind loading from Inez, with Vo = 68 m/s, has then, as a trial, been multiplied by a factor of 8, in order to cover several effects. The factor includes a nominal gust loading factor of 2, it allows for a more intense hurricane, and it still gives a further margin. As an example of a more severe hurricane, the lowest measured central pressure shown in Emanuel's 1988 comparison between measurement and his calculations was 870 mb, as compared with the 927 mb for Inez in the data used above. The wind loading on the tower as a first approximation would be expected to be proportional to the drop in barometric pressure at the centre. The factor of 8 should therefore allow for the strongest reasonably possible hurricane for the present global climate and still give a margin.

The writer has been advised that, in the 10 to 20° latitude region of greatest interest for the present discussion, there are non-hurricane winds which could give loading over the upper few kilometres of the tower comparable with the hurricane values discussed above. It would therefore need further work to establish whether the above loading specification were adequate as a representation of the non-hurricane winds. In the following discussion it has been taken to be adequate to put the factor of 8 on the distribution obtained from Fig. 4b with Vo = 68 m/sec.

It will be seen from Fig. 3 that the hurricane wind loading on the tower falls very rapidly with altitude and is close to zero for all the upper half of the tower. This fact is crucial to the practicability of the tower. At the base of the tower the wind loading that has to be accepted on a high moment arm is almost zero; and on the upper half of the tower there is almost zero wind loading of any sort. Consequently the upper half of the tower can in principle be of very light construction, while the lower half, influenced strongly by both the weight and the wind force from the upper half, need be only a very small fraction of the weight that it would have needed to be had the wind loading continued at a high value over the whole tower.

A brief parametric type of calculation has been based on the above wind loading factor of 8 applied to the distribution obtained from Fig. 3 with Vo = 68 m/sec. All the material in the tower has been taken to have the density of steel; also except for the diametral structure in the region of 4 to 8 km altitude, the structure has been taken to be equivalent to

all the material having a permissible vertical stress of ± 370 MPa. The last assumption would imply, for example, that if 50% of the material were taking a uniform vertical stress while the other 50% were fulfilling other functions and had zero vertical stress, then the vertically stressed material would have a permissible vertical stress of $\pm$ 740 MPa. A permissible stress of $\pm$ 740 MPa, with almost zero fatigue content, as here, and with well factored loads, seems to be just about attainable with a suitably tough and adequately ductile commercial steel, although that may need a great deal of further consideration. Temperature insulation is provided by cladding at the external perimeter of the tower, except that over the upper few kilometres the insulation may be limited to the structural members. An overall analysis of materials may be found for example in Crane and Charles' 1984 survey. The implication that on average 50% of the total weight could be fully stressed in any part of the structure would also need further consideration. The diametral structure in the region of 4 to 8 km altitude has been taken to cause a 40% increase in the weight of the tower when there are 32 spiralling tubes below 7 to 8 km and no central tube.

In the calculation the assumptions concerning the minimum wall thickness and the types of structure in the upper part of the tower appear to be extremely important. Now the top of the tower is stationary; moreover it operates in a near stationary, and cool, near vacuum, and carries near zero load. It therefore seems to the writer that it should be possible to give it an extremely light structure. For the present calculations the upper part of the tower has been taken to have a very light steel girder structure, which is external to the air tubes, and which is supporting a stainless steel skin for each of the 32 tubes and for the outer perimeter wall. The support is taken to be such that each skin will essentially be in tension. The skin has then been taken to reduce to a minimum thickness of 0.25 mm at the top of the tower; correspondingly at the top of the tower the weight of the total of the girder structure and the skin has been taken to be the same as for a wall thickness of 1 mm for each of the tubes and 1 mm for the outer perimeter wall. The 0.25 mm skin is slightly domed, locally, for stiffness, rather as for the transparent roof but more shallowly, and may have local stiffening ribs external to the air tubes.

On the above assumptions the required metal, as calculated for the walls of the 32 air tubes and for a continuous outer peripheral wall all at 1.5 km altitude, has a thickness of 250 mm or an equivalent in multiple sections or concentrated supports, together with another 50% of material contributing equally in vertical stress in components such as webs.

The above results give about the best possible proposal that the writer has been able to make for the tower if it has to meet the specification that it should be able to withstand the worst hurricane reasonably likely in our present climate. Subsequent cost analysis, however, by the very simplified methods mentioned in section 4 of Appendix II, did not seem encouraging. The required wind loading was therefore relaxed, by the argument that the earlier towers to be built would all be "upstream" of the regions where hurricanes form and that, in particular, the African West Coast region initially discussed is not a region of high winds - see, for example, Hayward and Oguntoyinbo, 1987. If, then, the wind loading is arbitrarily halved, so that the loads in Fig. 3 are multiplied by four instead of eight, the total amount of metal required for the tower is found to be divided by a factor approaching two. In view of the arbitrariness of the reduction in wind loading and the very many uncertainties in the tower design, the amount of metal required for the early towers, at least, and used for the main cost estimates of the writer, is therefore taken as a half of that given by the initial calculation. An alternative approach to the design of the tower would be to use a more open structure - as for the Eiffel Tower - below about 7 km altitude in order to reduce the wind loading. However, icing, local wind loading on the individual members, access, and corrosion, would all need consideration.

c. Installations over the ocean

For installations of the transparent roof and tower scheme over the ocean there are many additional considerations.

The main consideration is probably the market for the electricity and water - and for the created space. The present suggestion is that the attractive climate and the facilities which could be made available might justify converting the roofed area into a floating island - for living space. Occupations could include marine leisure activities and scientific study; in addition, with proper preliminary programmes of research and development, parts of the oceans could be used both for the farming of fish on a scale of geometry large enough to be fully humane, and for new industrial activities - leaving the greater part of the oceans as a protected reserve.

As regards the appearance of the island installation, the present suggestion is that about two-thirds of the roofed area would be converted into a floating island which would look, superficially, rather like the land based scheme of Fig. 1. The remaining area, consisting of about the outer third of the total area, would be transformed into endless sunny golden sands, palm trees and safe coral lagoons. The water of the lagoons would be ideally warm for the coastal-water fish living in it, and for the turtles, as well as for people and for power generation.

As most of the areas of interest for hurricane control are over the oceans, and as hurricanes themselves use heat from the ocean, it is relevant to consider also the use of heat from the ocean in the system of the above discussion, instead of almost direct solar heating.

In principle the warm air for the flow in the tower in the above discussion and in Fig. 1 could be obtained by passing ambient air through a heat exchanger taking heat from the ocean, instead of direct solar heating, before passing it to the turbines. Such an arrangement may prove to be adequate. However, because of the ocean temperatures available, the heat exchanger required in some situations may be very large and the effectiveness not very great - if that were not so hurricanes would be likely to be much more frequent than they are.

The situation can perhaps be improved by placing the heat exchanger downstream of the turbines instead of upstream. For, given that the system is functioning strongly, there is a significant drop in both the temperature and the pressure when the flow has passed through the turbines. It is then possible for the flow to receive a considerable amount of heat from the ocean in a more moderate sized exchanger. However, the heat so received from the ocean, although considerable, may still not be sufficient to cause the system to function "strongly", as postulated above. Consequently, some further action may be required. That might be provided by a "booster".

The booster seems able to take any of several possible forms, according to convenience. The air could be heated further by warm water from a solar system, heat could be "pumped" from the ocean, or fans could be used to raise the pressure and temperature after the heat exchange so that their values actually in the exchanger were further reduced. The solar boost seems to require about a third to a half of the total heat input to be supplied by the sun's heating for what seems to the writer to be likely to be a reasonably proportioned heat exchanger. On the other hand the fan system dispenses altogether with the need for direct solar heating and so can function all and every day and night, without hot water storage, and in a generally much more compact form. There is, however, an appreciable loss of efficiency with the fan system - down from 20 to 25% to perhaps 15% according to the

very rough estimate of the writer. There is also a high pressure loading on the roof of the heat exchanger and on the subsequent ducting.

In order to make the heat exchanger as compact as possible it would probably have vortex generators, such as the three-dimensional aerofoil of the main text, in order to maintain fresh fluids at the interfaces. The system would also need to be of low aerodynamic losses, with channel type flows rather than having water freely dropping under gravity as in cooling towers.

The above general arrangement of putting the ocean to air heat exchanger downstream of the turbine is analogous to the effect emphasized by previous authors that the drop in pressure towards the centre of a storm enhances the heat pick-up from the ocean. In the storm the fall in air temperature with pressure is largely compensated at the surface by the dissipation of the kinetic energy, as for a boundary layer on an insulated dry surface. Consequently in the storm it is mostly only the drop in pressure that causes the enhanced heat pick-up. In the heat exchanger the temperature drop also enhances the effect, as does the booster.

Particularly when the heat is obtained from the ocean, a starting mechanism could be needed for the total system. This might be provided by driving the turbines as fans, with the power taken in reverse from the electrical grid connection.

c(i) Structure of a floating island

The island is thought of as basically a conventional compartmented box structure. It would be continuous horizontally in all directions, have stiffening internal to the box structure, be about 4 metres deep and have 6 mm mild steel plates proofed against corrosion as the upper and lower surfaces. Such a structure would readily carry a load of say 2 Tons per square metre, distributed, in addition to spaced local loads each of 1,000 Tons. The material costs for the total steel plate of the above structure could be in the region of £70 per square metre of island area. The corresponding total costs for the whole island would be large. However, when shared between all the people and organisations, it may be considered not unreasonable. It would exist instead of the usual market cost of land suitable for building. It would also implicitly include foundations, very low cost future heating and air conditioning, and many facilities and generous open spaces as part of the associated arrangements. Moreover, the transparent roof and solar panels, with the air conditioning, would fulfil some of the requirements of the roofs and walls of conventional buildings. Consequently, the direct building costs for houses, shops and factories on the island would be small, given the basic structure and arrangements of the island.

The costs for the above structure of the floating island are not at present put against the electrical power generation. To some extent they have already been discounted in taking only a low capital cost as justifiable for the electricity generation. However, they would form a large component to be accounted in any more accurate overall assessment.

c(ii) The tower over the ocean

The tower would readily float on part of the island. The corresponding metacentric height stability would be very large.

c(iii) Possible use of natural islands

Many of the hurricane areas of present interest have a large scattering of natural islands. These might be used, if the people and governments agreed, for building the towers. Alternatively, the islands might be used as a relatively easy mooring for a floating island, after the tower had been built at a shipyard and delivered, floating.

c(iv) A possible low cost construction method for a floating tower

The floating type of tower could be built in modules, assembled in a suitable area of possibly fresh water with the use of flotation components. The assembly could then all be carried out at surface level and the tower raised progressively by the flotation components. The upper parts of the tower may need temporary stiffening against low level winds during construction. Such a method of construction could very much reduce the costs of the tower.

c(v) Ocean currents

Subject to further study, it seems from Meiklejohn that some of the regions of interest not having natural islands do have areas where the speeds of the ocean currents are fairly low. For example, the Bay of Bengal has a complex geometry of ocean currents and some of the more important areas seem to have only low speed currents. It then seems, from Meiklejohn, that units such as in Fig. 1 could be sited in areas with only low speed currents and yet give a reasonable percentage cover of the region. That might make it practicable to maintain the units adequately on station by a system of propellers. A current of say 1 knot would seem to require about 2% of a unit's electrical output power for the unit to maintain station ordinarily in this way. Storms would need special consideration in order to decide how much movement temporarily off station were acceptable. A very large keel and rudder system would be needed to control movements during a hurricane.

<u>d.</u> <u>The rate at which hurricanes might be affected</u>

In order to find the rate at which hurricanes might be affected by the above developments, very tentative estimates will be made of the possible rate of building and of the areas required to be covered. Also, the principles involved will first be re-iterated.

d(i) Review of the principles on which the transparent roof and tower system should reduce hurricanes

Basically, the transparent roof and tower system should remove the heat from which the hurricanes would otherwise develop. In more detail, the following would be expected.

(1) The atmospheric air passing over the transparent roof of one of the units should be insulated from the heat and moisture of the ocean. There would therefore be less heat and moisture going into any storm or embryo hurricane situated either downwind or over the unit.

(2) When built on land, the atmosphere would similarly be insulated from the sun's heat.

(3) Some of the highest heat content air usually available to the storms would instead be taken by the unit and ejected from the top of the tower above the level of

the storms, without mixing with the air of the storms, and therefore entirely bypassing them.

(4) The units would probably cause a reduction in the temperature of the surface of the ocean downstream of the unit because of the shielding from the sun's heating and the mixing with the water at depth.

(5) Dependent on usage, the cold air and cold water from the tower could perhaps contribute somewhat to a genuine cooling of the storm and a discouragement of convection.

The above effects would "starve" the potential hurricane vortices of heat, moisture, and convection and would therefore cause them to decay instead of growing into hurricanes.

For the rare occasions where a developed hurricane or tornado crosses a unit and causes the roof ports to open, as in Section a. of this Appendix, the "warm lagoons" on the outer edges of the units as in Section c. may need special treatment.

d(ii) The rate at which transparent roof and tower units could be built

Suppose, particularly with the improved international situation referred to earlier, that investment and economic growth rates increase above today's values. Suppose that global productivity per head increases at 4% p.a, and that the world population increases at 1% p.a. Suppose also, that from the year 2000 AD, 1% of global income is invested in the "electrical generation aspects" of the transparent roof and tower system. Suppose that those aspects initially cost say £500 per kilowatt of installed capacity - with parts of the remaining 99% of global income being invested in the many other aspects of the system such as housing, hotels, irrigation, landscaping and sports equipment. Suppose also that in real terms the installation cost per kilowatt falls from the initial £500 in 2000 AD at the rate of 4% p.a. - partly perhaps by a progressive increase in scale giving an improvement in the economy, and partly perhaps because of design improvements and improvements in materials. With all of these assumptions the number of 100 km square units, or equivalent, which would be built is shown as a running total in Fig. 3.

The above assumptions are all rather favourable to the present argument. On more neutral assumptions the programme would start later than shown in Fig. 3 and the curve of building rate would be shallower.

d(iii) The units that would be required

For the estimate of the world's area which is required to be covered a reasonably accurate estimate should become possible by suitable adaptation of current meteorological methods of calculation. The present suggestions merely represent a postulate on the part of the writer of the coverage that might be found to be required. The information considered here is broadly that discussed in the earlier paper, in particular Tingley's discussion for Central America, Tannehill's survey, Mitchell's discussion and correlations, the large amount of work from many writers on North Africa, and Gray's data of 1968.

It is suggested that a high proportion of the North Atlantic hurricanes will cease if the vortices, or waves, in the easterlies could be weakened when crossing the strip of land immediately prior to the African west coast. It is now postulated that, if the people and governments of the land agree, the most economic arrangement overall in that region could be a combination of the present Fig. 1 type system, which removes heat, with water spray.

The water spray would cool by evaporation, using the water made available by the system of Fig. 1. (If the water spray were not effective against hurricanes, then more of the present units would be required.) One of the present units as in Fig. 1 would cover almost 3% of the land area previously discussed. Then, it is suggested say five units as in Fig. 1, together with water spray on a half of the remainder of the land area, could reasonably be expected to make a significant improvement. Possibly, it seems to the writer, there could be a reduction in the number of hurricanes that subsequently developed over the Atlantic to only a small proportion of the previous number that did so.

For Central America, from the discussions of Tingley, Mitchell and Tannehill, and from the eastern Pacific region of Gray's chart, the area of the regions in which hurricane embryos first form seems fairly compact. It is therefore suggested that a reasonable treatment could be a 20% coverage of these areas by units as in Fig. 1. (No benefit is assumed for any external waterspray.)

For the western Pacific and for the whole of the region of the Indian Ocean, Gray's chart suggests that the regions where hurricane embryos form are very diffuse. On the other hand, Gray's chart for the development into hurricanes appears to indicate much more compact areas. It is therefore postulated that it would be more effective to cover the latter areas at say a 30% coverage, than to cover the more diffuse regions where the embryos form even if these required only a lower proportional coverage. All comparisons need much further work - and it could be that particular critical areas may be found as in North Africa. For the present estimate, however, the 30% coverage of the more concentrated areas is taken as a target.

With the above postulates the 100 km square units that would be required in order to reduce the total of global hurricanes to perhaps a small proportion of their present number is as follows:

Coastal region of northern Africa (for the North Atlantic)	5
The sea east of Central America and Mexico	30
The sea west of Central America and Mexico	70
The northern west Pacific	270
The southern west Pacific	100
Bay of Bengal	50
Arabian Sea	30
Indian Ocean (south of the equator)	125
TOTAL	680

d(iv) Effectiveness of the hurricane aspect of the programme

The various numbers of units in the above list may be compared with the running total that might be built as shown in Fig. 4.

A first conclusion is that a strong reduction could be possible during the next few decades - say during the first half of the next century - in all regions where critical areas for hurricane control are either already known to exist, or seem likely to be found.

A second conclusion is that the global total of hurricanes might be reduced to a small proportion of the present number after five to ten decades, - say during the second half of the next century.

It is conceivable that the above improvements could be obtained at virtually zero cost to the hurricane control programme.

e. Reference to mobile units

The main text includes a brief discussion of possible mobile units, which, if practicable, might allow a very much shorter and more economic programme of hurricane control compared with that shown above. The combination of the factors discussed in the main text and the method of construction suggested in section *c(iv)* of this Appendix could give mobile units a very good economy. However, the concepts involved would need further study even for a preliminary assessment of their practicality.

The high altitude jet exit in a mobile unit could be deflected rearwards in order to provide thrust instead of drag. The electrical pick-up could be from T junction cables connecting to the main cable say every 5 km. The main cable layout would be under the possible routes of the unit and a continuous hawser could link the access cables. A somewhat similar arrangement might allow collection of the fresh water production, which could be very much greater than suggested for a land based unit. Relatively small buoyancy compartments controlled from the unit would be sufficient to raise the connecting ducts and cables ahead of the unit and lower them behind it, with communication by tubes along the hawser.

f. Possible reduced capital costs for the solar heated system

From Section a. of this Appendix - it seems possible to argue that most of the transparent roof might be operated with both a very small temperature difference and a near zero pressure difference across it. One might therefore wonder whether the system could be made to function either without the roof, or with a much reduced roof area. A related possibility was mentioned at the end of section a. of this Appendix.

The essential features that would remain would be the cooling of the surface air by water spray and its collection and possible further heating near the centre; the flow up the tower would then occur as before at the centre. The practicality of such an arrangement would need further study. It is perhaps more suited to land situations, rather than to ocean units, as over the land the air close to the surface could more readily be kept simultaneously both cooler, and of considerably higher heat content, than the air brought down from altitude by the turbulence eddies of the natural wind

g. A preliminary comparison with Schlaich's "solar chimney"

The present proposals have similarities to Schlaich's "solar chimney", as reviewed by Taylor, 1983.

Schlaich's use of essentially dry heat gives higher Carnot efficiencies than for the present proposals for a given altitude of tower exit, particularly for low exit altitude, where the present proposals would have a very low Carnot efficiency. However, because the starting point for the present proposals has been the simulation and prevention of hurricanes, the present proposals make use of moist heat and are essentially related to towers which are extremely tall. Such a starting point implies the acceptance and solution of problems of moisture removal and icing prevention in the tower, and the design and construction of a building so tall as to be outside current concepts of civil engineering. It implies also a low cost method of collecting heat from a very large area. Nevertheless that starting point, related to hurricanes, also brings its rewards. If the above tower is in fact attainable, then the real efficiency and power output on the writer's calculations do seem to be so large that

they might reasonably be able to pay for the cost of collecting the solar or ocean heat, as well as for the cost of the tower itself and other associated items. Moreover the hurricane starting point also allows the use of only slightly warm air and therefore allows only low heat losses across the transparent roofs, it eases the heat transfer from stored hot water, it introduces the ideas of generating cool air and fresh water and allows apparently useful integration with social living and the environment and agriculture, and it allows the use of moist heat from the oceans - in addition to being able to prevent hurricanes and influence global temperature, in ways additional to the reduction of the greenhouse effect. But the present proposals are very much more complicated than the solar chimney.

h. Integral generators for the electricity

The turbines in the present proposals are likely to have large diameters and fairly low tip speed. Conventionally, therefore, they would be geared to electrical generators on shafts which are separate from those of the turbines. However, the present turbines could have very large hollow aerodynamic blades. Consequently, a lower cost arrangement may be to put the electrical rotors within the aerodynamic rotor blades, with the electrical stators placed immediately outside the turbine annulus casing at the tip of the rotor blades. Both the gearing and the torque transmission would then be eliminated, as well as the separate electrical rotors.

i. Long distance transfer of warm water

The costs of transferring warm water from the tropics, for use in temperate or polar latitudes, might also be worth consideration. Large ducts resting on the ocean floor might be relatively light.

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APPENDIX II

Discussion of the Concepts Behind the Present Invention and of Further Embodiments of the Invention

1. Introduction

The development of a hurricane can generate very large quantities of kinetic energy sometimes within a few days. One might therefore wonder whether the situation could be usefully simulated. The present suggestions seem at first like science fiction - and maybe are only science fiction - but in their smaller scale versions at least are put forward for consideration as a basis for real projects.

2. Some features of hurricanes

Emanuel (1986) has shown that the Carnot efficiency of hurricanes is about a third, as a result of most of the heat being added to the airflow at the sea surface at about 300°A and removed at high altitude at little more than 200°A. Between these two temperature zones the expansion of the air as it rises in altitude occurs approximately isentropically, in the eye wall. The recompression and return to the surface is more complicated, but for present purposes may be taken as isentropic after the initial heat removal.

The features of particular interest in the above thermodynamic cycle are the reasonably high Carnot efficiency and the use of very "low grade" heat - in fact heat at about ambient temperature. Very large quantities of low grade heat are available in the world and the reasonably high Carnot efficiency could perhaps justify its collection and usage.

Two other features of hurricanes are also of interest, their large rainfall and their cool downdraughts. The large rainfall occurs because of the very high updraughts of moist air. The cool downdraughts occur when the precipitation falls through the drier and lower heat content air at mid-altitude, indicated for example in the basic tropical profiles given by Jordan, 1958, Gray, 1968 and Reed 1978.

3. The simulation of hurricanes - general approach

The simulation of hurricanes has obvious problems. The first proposal put forward below, section 4, uses as it were an extrapolation of existing methods of engineering construction, but would produce a project scheme that could be unattainable because of its scale and difficulties. A formal estimation of costs indicates that such a project could be economic under some circumstances if the scale were large enough. A second proposal is put forward in section 5 using less conventional techniques and, from a very crude analysis, it seems just possible that the performance could be economic and the scales acceptable. A third proposal is put forward in section 6a, as a progressive extension of a possible small scale pilot project.

The very large scale and maybe unattainable unit of section 4 is given first in some detail, as an idealised concept, as the principles are straightforward in that scheme and the description easier.

The mechanics of the vortex of the hurricane are not used in any of these primary proposals.

Some further proposals are discussed in sections 6b and 6c.

4. An idealised concept

The basic unit for the first, very large scale, proposal is an area of land 100 km square, having an essentially flat transparent roof at a height of the order of 100 metres, together with a central tower rising to an altitude of about 10 to 17 km. The diameter of the tower would be about 5 km at the top and 12 km at its base. Part of the area just under the transparent roof would be covered by solar hot water panels. Elsewhere, water would have been sprayed into the air, in order to obtain the desired temperature and humidity for the given solar heating and chosen air flow. As a result, warm moist air would be passed from under the transparent roof, through heat exchangers and turbines and then through to the tower. Such an arrangement, under favourable conditions, could give 10^9 kw of electricity averaged over 10 hours of daylight, a peak at any time of 3×10^9 kw by use of hot water from storage, and a nett output of fresh water in the region of 2 to 5×10^7 Tonnes per day. A relatively simple and low cost method of construction appears to be possible for the roof. Also, the tower is less difficult than might at first be thought, because of the low atmospheric densities and very low wind loading at very high altitudes.

The above electrical output may be checked briefly from Kiely (1977) which quotes contours of solar radiation received actually at the earth's surface. Solar input in much of the tropics is between 0.2 and 0.25 kw per square metre averaged over 24 hours, or about 0.48 to 0.60 kw m^{-2} averaged over 10 hours of daylight. The corresponding ideal output for a Carnot efficiency of a third and a solar heat collector covering an area of land 100 km square would therefore be about 1.6 to 2.0 $\times 10^9$ kw. The reduction to 10^9 kw allows for heat losses of the heat collector, aerodynamic losses in the ducting and turbines, electrical and mechanical machinery losses, losses associated with carrying moisture and precipitation to altitude, miscellaneous losses, and some gain from the heat extraction from the moisturising water. At "design", the heat addition for each unit flow of air has been taken to be about three times the value for a hurricane - partly to economise in the size of the ducting - and the corresponding rise in the "equivalent" temperature of the air, i.e. the dry temperature rise equivalent in energy to the moisture addition, is about 66°C, with ducting air velocities mostly between 5 ms^{-1} and 30 ms^{-1}. At peak output, the power is trebled by doubling the air flow and increasing the heat addition per unit of air flow by about 50 per cent.

The overall circuit flow should be very stable. The high specific heat input compared with hurricanes would give a warmer and therefore more stable flow in the tower, compared with the rising flow in the hurricane eye, particularly as the adverse rise in ambient potential temperature with altitude would be the same as for a hurricane. Moreover, the fairly high speed turbine locked in to the electrical grid would sharply decrease the work extraction during any unscheduled reduction in air flow and therefore give strong stabilisation. The local flows in the tower should also be stable. The possibility of pockets of reverse flow such as occur in the eye wall of a hurricane would need to be checked, but the fairly high speed mean upward flow of air in the tower would be expected to "sweep away" such pockets - by shear stresses and a skin friction component of favourable pressure gradient - provided the arrangements to be discussed work well for separating the precipitation from the air flow.

The size of the unit above has been chosen to suit the economics of the tower. At the resulting scale chosen - still very much smaller than for a hurricane, by a factor of about a hundred on power - the input of solar heat to one of the above units is of the order of a quarter of the existing total rate of energy usage by the world - with the world usage based on the 1978 data of Counihan, 1981.

The nature and large scale of the unit makes its economy very dependent on successful integration with the community and with the environment. In this respect the coastal region of West Africa is of interest for a first consideration, if the peoples and governments of the region agree, for reasons which will be discussed in the following paragraphs.

From Kiely (1977) the region mentioned is seen to have a reasonably high power input, while the more detailed information of Duffie and Beckman, 1980, shows that the seasonal variations are probably less than $\pm 20\%$. Now work on hurricanes shows that most Atlantic hurricanes develop from atmospheric vortices which pass over the above coastal region of West Africa, between latitudes of about 10° and 17° north, as may be seen, for example, in Mitchell's 1924 analysis and the work of Carlson, 1969. Subject to a proper analysis, it will be assumed in the present proposals that the removal of solar heating over about 30% of the above coastal region, to a depth inland of 500 km, would provide a significant reduction in Atlantic hurricanes. The equivalent of perhaps ten of the above units might therefore be required for significant hurricane prevention. Moreover, as the region is upstream of the hurricane formation zone and somewhat south-west of the high altitude high velocity jet streams, its maximum winds are not high, as discussed by Hayward and Oguntoyinbo, 1987. The design of the tower is then much more practicable than in a region of high velocity winds. There is also some high ground - Fouta Djalon - on which to build the first tower. And finally, Hayward and Oguntoyinbo argue that the whole West African region already has a population of 160 million people and that is expected to double within the next twenty years. Those authors then argue that for a successful human and environmental development of the region it will be extremely important that both the difficulties and the opportunities of the climate are taken into account. The difficulties which they discuss are caused primarily by the high temperatures of the air, with, in some areas high humidities, and in others low and unreliable rainfall.

From the above types of consideration the sort of arrangements which might be developed are rather as sketched in Fig. 1 and 2. As a preliminary, the tower brings down and cools and moistens by water spray air of low heat content taken from the atmosphere at 2 to 4 km altitude. The resulting cool air is circulated as "out-of-doors" air conditioning to an urban conurbation within part of the roofed area. This urban conurbation is shielded from solar heating by the high level water panels and from the electro-static fields of "thunder weather" by the steel roof frame mentioned below. The conurbation therefore has effectively a form of cool artificial urban climate. Suitable agriculture, together with landscaping, sport and other leisure activities, may occur elsewhere under the transparent roof. In the latter areas probably the main airflow enters through holes flush in the essentially flat roof, so that wind loads on the roof are kept near to zero. The paths of the airflow are arranged to ventilate the space immediately under the roof, for the whole unit, in order to keep heat losses to a minimum. The supporting framework of the roof is in light structural steel, suitably protected, in (inverted catenary) arches - rather like the vaulting of a gothic cathedral - with the transparent panelling in slightly domed plastic 1 mm thick. The tower would be largely in structural steel, suitably protected against corrosion, with insulating cladding on the outside of the tower and heating as necessary to prevent low temperature brittleness; the upper few kilometres would be partly in stainless steel, with local insulation and heating for the main structural members. The warm air flow in the ducting of the tower might have swirl, or be in helices, in order to allow extraction of the rain. Icing of the walls would be prevented by a sudden expansion of the ducting at one or more levels, arranged to prevent freezing rain reaching the walls, together with intermittent radiant heating. The through draught and the upwards airflow in the tower would be "started" if necessary by driving the power-turbines as fans and possibly having the airflow warmer than at design.

The output of electricity from the above arrangements would be at a very large scale and is therefore taken to allow electrical transmission not only to the total West African region considered by Hayward and Oguntoyinbo, but also to the market of Europe. Surplus off-peak electricity might be used for producing clean artificial fuel or possibly for re-charging power batteries for road transport. Then, for a very preliminary assessment of the possible economics, and subject to very much more study, the total cost of the principal raw materials has been crudely estimated - steel for the tower and roof, plastic for the roof, and metal for the water panels, all in their unformed state, i.e. flat sheet or ingot. That cost seems on the writer's calculations to be perhaps as small as 10% of the allowable total capital cost of the project - the allowable cost as based largely on the possible market value of only the electrical output. Moreover, the manufacturing costs to be added subsequent

to the provision of the material, as a ratio of the cost of the material, could be very much less than in many engineering situations. It seems to the writer, therefore, that, in principle commercial success may not be impossible, especially if the artificial climate could be included as a substantial commercial benefit - but the form of proposal in this section 4 has obvious difficulties.

The effect on the water balance for the rest of Africa would need careful checking and control. Broadly, it seems to the writer that the balance could be favourable if the water produced were not allowed to drain to the ocean, but instead were (eventually) used for careful irrigation and re-evaporation. The irrigation should be adequate for a considerable area of local land and should give some local protection, at least, against sand storms.

Development of the above arguments leads to possible schemes over oceans, perhaps with the heat being taken from the ocean in relatively compact heat exchangers. Such installations could be mobile, so that they might be able to avoid all very high velocity winds and use areas with the most favourable ocean temperatures. Moreover they could in principle be built by progressive flotation working almost entirely from surface level. Somewhat similar arrangements might be practicable in regions such as in the North Atlantic, where the continuation of the Gulf Stream brings northward relatively warm water from the tropics. The towers in the North Atlantic would probably reach to an altitude of 5 to 10 km because of the lower tropopause. The high radiation lobes over the two continental regions between 50° and 70° north (Kiely 1977) might also form good energy sources - in positions where an artificial urban climate could be helpful in place of both the summer and the winter natural extremes. The maximum Carnot efficiency would be much lower at the higher latitudes, compared with the maximum tropical values, because of the much smaller temperature range within the atmosphere.

An additional result, in the very long term, if we were able to develop the appropriate predictions, is that there would seem to be possibilities for the control of world temperatures. The effects considered for that result are additional to the influence on the 'greenhouse effect' and are partly due to changes in cloud cover. There seems also, conceivably, to be possibilities for the prevention of ice ages. However, great care may be needed to remove a very high percentage of the ice crystals in the exit flow at altitude, perhaps by a form of electrostatic separator after thorough removal of the precipitate at lower altitudes. Study of the high level movements and effects of ice crystals in natural storms could give some indication of what would be necessary in that respect. The ice age effect is thought of as following Hoyle's 1981 discussion and would be achieved, when the global scale of operation of ocean based units is large enough, by providing clean air at very high altitude. The advantage would hold after large meteoric type collisions with the earth and there should be similar cleaning after volcanic eruptions.

A second proposal is now put forward, based on unconventional techniques, in an attempt to reduce the scale and achieve greater flexibility.

5. Reduction of scale

The second proposal is for the tower discussed above to be replaced by a "self supporting duct", based partly on balloon technology. In appearance the duct would be rather like a large wind sock. The "sock" would be inclined at a shallow angle to the horizontal, probably in the region of 20°, in order to reduce the wind loading, as that is the largest factor contributing to the cost of the tower. Also, it would have an outer annulus of helium and air (separately), or heated and insulated air, under slight pressure, to provide buoyancy and to resist the inward pressure loading from the atmosphere. Shape control for the circular section would be given by the combined effect of internal tension members in the outer annulus and the gas pressure. This shape control to circular may be relaxed near the exit, in order to allow a more flattened section and therefore a closer to optimum exit altitude for the higher and for the lower streamtubes of the flow. The reduced wind loading for the

sock, as mentioned above, follows from the very much reduced dynamic head of the wind component perpendicular to the axis of the sock and the reduced bluffness of the section for the total boundary layer flow - which is still approximately horizontal. Heated air seems the more likely buoyancy medium because of the cost of helium. The air could be heated electrically, with some direct solar contribution. The material for the sock seems likely to be some form of plastic sheeting, reinforced by, or together with, perhaps steel cabling.

The anchorage for the sock would allow the sock in plan view to rotate to lie along the wind; it would also allow it to rotate very slowly along its length axis in order to help clearance of snow and ice. The second rotation could be cyclic, so that it would not necessarily require a true bearing. The sock would have a concertina type section to give easy bending to follow changes of direction of the wind with altitude. In addition it would have automatic or remote control of the volume and pressure of the helium or hot air - or air temperature - at each level in order to allow altitude control in strong winds and ease of bending. The altitude control could be used also for varying the exit altitude in such a way that the ambient temperature could match the exit temperature of the internal flow even when the internal flow were operating at "off-design". Alternatively the control on exit altitude could be used for avoiding very strong winds at the higher altitudes. Ice and snow control may additionally require intermittent local heating, while considerable insulation would need to be provided between the inner flow and ambient. The stability of the sock in bending would need careful study; some damping in vibration would be provided by subdivision of the buoyancy annulus into compartments and the provision of bleeds between suitable compartments - such as between a pair positioned across a diameter.

The lay-out adopted for the total system would be for the sock to be situated both remotely from airports and at adequate distances from areas of high population density, with the heat transported to the sock, from several urban areas, entirely by hot water. The central districts of the urban areas, as well as the districts with high densities of housing or factories, would probably have the transparent roof and solar panels rather as in section **4**, while elsewhere the panels might be more conveniently mounted on the roofs of buildings and additionally as appropriate.

A large rise in water temperature would be desirable in the solar panels in order to ease the heat flow elsewhere in the system. Consequently two or more stages of heating might be adopted with the water in the early stages passing through transparent panels if these can be maintained free of deposits and growths on the walls. These transparent panels, would, in particular, more directly transfer to the water the re-radiated heat stopped by the transparent layers. A whole array of multiple pass water flows and insulating air spaces might be manufactured from multiple thin flexible sheets by a process rather analogous to that used for bubble sheet packaging. The water would be cooled at the cool end of its cycle by the air flow which would be passing from the ambient into the sock. The cooling would be by both moist and dry heat transfer, so that the cooled water could be close to the ambient dew point and the warmed air not too far from the warm water temperature. There might subsequently be further cooling of all or part of the water by "anti-freeze" brought down from the walls of the sock at altitude.

The hail and cold water production would be available to provide some cooling for the "out-of-doors" air conditioning in the urban areas. However, there could also be cooling from combined air conditioning - heat pump units that in the urban areas pass their exhaust heat to the water going to the solar panels. If the efficiencies of the heat pumps were closer to the ideal than usual, the increased electrical output from the sock as a result of operating the heat pumps could more than compensate the usage of electricity by the heat pumps, as the proportional temperature drop along the sock could be much greater than the proportional rise at the pumps. In a sense the result would be much better than perpetual motion, as it would give additional nett power output without any intentional heat input, as well as air conditioning.

From the above arguments there may now be neither warm nor cool major air flows under the transparent roofs, but instead only local cool flows. The roof and its supports could therefore be scaled down in height and in local design compared with that in section 4, in order to allow thinner material and lower total costs and to suit local requirements. Considerable flexibility would then be possible in the manner of building under the transparent roof. The transparent roof, together with the solar panels and air conditioning, would fulfil some of the conventional requirements of both the roofs and walls of ordinary buildings - such as houses, shops and factories. Consequently it may be possible to develop a building method loosely analogous to the internal partitions of some modern offices or to the arrangements for modern open plan offices. Alternatively, the transparent roof and solar panels and their supports could be integral with the buildings below them. Either way a relatively high standard of accommodation at relatively low costs might be possible over the full range of wealth levels. The present proposals might therefore start to be applicable even at the present levels of wealth, with some contribution to the costs of the proposals coming from the savings relative to conventional building costs. The transparent roof and solar panels could fairly readily be interrupted as required in order to allow urban open space for recreation. The solar panels under the transparent roof would probably be arranged in staggered arrays so that most of the direct sunshine were intercepted at midday but some came through at other times and considerable areas of sky were always visible. Most of the panels may be at the upper staggered level and integrated with the panels and structures of the transparent roof, for lightness, low cost, and a wider choice of transparent material, including perhaps glass. Such an arrangement might also ease the problem of security.

The economics of the sock and of the total system as indicated above have been considered very crudely, mainly by comparison with the wind and gravity loadings calculated for the tower unit of section 4. The analysis appears to indicate a possible scaling down from the proposals of the tower unit by a factor of about a hundred on power output, for what would seem to be - at least very roughly - about the same non-dimensional performance both technically and economically. (The internal diameter of the sock at ground level could then be about 0.3 km.) A somewhat larger scale than the smallest economic could become appropriate, however, in order to reduce the overall interference with aerial navigation. Some form of grouping of the units could reduce the interference with aerial navigation from a large number of units.

Another possibility with the sock is that it could be "wound in" prior to high winds. The total global electrical production and system of transmission would need to be arranged to be able to allow say any 10% of the production from sock type units to be dispensable at any time, in addition to the ordinary requirements of maintenance. The removal of the buoyancy medium from the lowest concertina section and the lengthwise closing up of that section, followed by the progressive repetition of the process, would then allow the whole sock to be stowed safely for the high wind period. Such an arrangement for winding in the sock may greatly improve the commercial prospects of the system because of the technical difficulties and costs of building the sock or the tower to withstand high winds. The corresponding reduction in scale compared with the sock without winding in could be by a factor of perhaps ten on power, according to order of magnitude calculations by the writer. At that reduced scale the peak output would be in the region of 3×10^6 kw, i.e 3 Gw, which is about the size of conventional power stations. The atmospheric pressure load across the duct wall has then become the main loading in place of the wind, with the increasing length to diameter ratio of the duct restricting further reduction in scale.

A variant on the sock just described could be to use a duct much closer to the vertical - say within about 30° of vertical - with the wind loading reduced by an aerofoil section fairing. The aerofoil would be kept facing in to wind by a "weathercock" type stability in combination with suitable torsional flexibility along the duct. The buoyancy medium would probably be between the fairing and the annulus. The smaller scale of a scheme with winding in could be particularly suited to such an arrangement. The smaller diameter would more readily allow the required torsional flexibility while the winding in might be used additionally for avoiding or clearing external snow and

ice. The winding in might also be used for avoiding, perhaps, even moderate winds, dependent on the geographical situation and the extent to which large scale electrical power grids have been developed for aggregating widely dispersed sources both of supply and demand.

In a development from the above it may just be practicable to use balloon type technology more generally for the near flat transparent roofs, including, also, for the solar hot water panels, in order to reduce costs. However, the security problem may then be more difficult.

a. Use of dry heat

In the above proposals for the sock the partial use of a form of dry heat addition to the main airflow has been taken from the work on the "solar chimney" as analyzed by Haaf et al, 1983, and reviewed by Taylor, 1983.

The "solar chimney" uses entirely dry heat and is discussed in connection with chimneys of modest height. Dry heat gives higher Carnot efficiencies than moist heat for a given exit altitude of chimney, particularly at low exit altitudes, and even at 17 km Emanuel's 33% for the Carnot efficiency could become nearly 40%. On the other hand for a given heat addition to the air, moist heat requires a much smaller temperature rise than dry heat. Consequently for moist heat the heat exchangers will tend to be smaller and more efficient and the solar heat collection and transport also more efficient. The compromise suggested above for the system with a sock follows from such considerations.

Another compromise for the total system would be to increase the proportion of dry heat and to reduce the altitude reached by the sock to an intermediate value. For example, purely dry heat would give an efficiency approaching a half of that attainable at 17 km exit altitude when using only 7 to 8 km. At 7 to 8 km exit altitude there could be some water production, but the internal temperatures could in principle remain above O°C so that the internal flow might avoid icing problems, while the sock would be very much smaller.

6. Pilot projects and other proposals

The present suggestions for pilot projects are based on using mountains to support the rising ducts.

Bartholomew's World Travel Map: INDIAN SUBCONTINENT, 1990, shows a substantial number of mountains in the Himalayas each rising in distances of 10 to 20 km from a valley floor at an altitude of 1 to 2 km to a large area of mountain top at 6 to 7 km altitude. Consequently, if the peoples and governments agree, pilot projects could conveniently be based on the replacement of the tower or sock by an insulated transparent duct running part or all of the way up one of the Himalayan mountains. In the later stages of a project, a shortened tower or sock could be placed at the top of the mountain duct. The main heat source could be a transparent roofed area of say 3 to 5 km square situated in one of the hotter regions of the plains to the south. Hot water would be used to transport the heat from the plain to the mountain. This arrangement on completion could give a scaling down of the power output of the original large tower unit by a factor of a thousand. Moreover, the arrangement could be built up gradually as a working project, even within the one thousandth scale. The project would allow field testing of many aspects of the main proposals, including in particular the removal of precipitation and the prevention of ice - but while working from the local ground level. The design of the inclined duct could be eased by placing turbines in stages at intervals of about 3 km of altitude, with controlled matching, in order to maintain only a small and maybe outward pressure load across the duct walls - perhaps also a feature of the sock if electrical superconductors can be employed.

A variant on the above pilot project would be to design a scheme rather as above, but to a somewhat larger scale of say 10 to 15 km square for the transparent roofed area of the main heat source, and, then, to start the building of the main heat source working mainly towards and along the valley from the lower part of the mountain face. The transparent duct on the mountain face would provide both heat source and rising duct, so that, again, the project would provide working experience from an early stage of the building. The scheme in principle would be much simpler than having a heat source situated on the plains to the south and, with careful planning, seems to have environmental and economic attractions.

In any of the mountain arrangements the ducts would preferably be formed primarily, by "roofing across" in a valley, or sloping valley or ravine, for ease of geometry and reduction of wind loading. Such ducts, of very large volume, might preferably be constructed using balloon technology, for low costs, particularly for a pilot project. The roof surface would need to be dynamically stable in winds even where the nominal loading were low, so that it could be advantageous to be able to "wind in" the system say laterally within the ravine.

a. A third main proposal

If the peoples and governments both continued to agree to the present type of scheme the pilot project for the Himalayan mountain and the plain to the south could be extended into a permanent installation.

Now one of the problems with such a proposal could be to avoid spoiling large areas of natural land. The problem may not be significant in the Himalayas as there the ducts could rise very steeply. If however, it were found from the design studies that the problem was still important, a solution might be to compromise on the thermodynamic efficiency by delaying the heat addition from the hot water until some particular controlled range of altitude. The heat addition could then still occur in the neighbourhood of 300°A and yet the subsequent air flow need not represent a serious hazard in the event of a failure of part of the system. Consequently it would then be possible to integrate the whole arrangement with the community. A nearly flat transparent roofed area rather like

that of section 4 could cover a valley, or ravine, running to the top of a mountain, with the heated air duct in the larger upper part immediately below the roof and a living area below. The middle and upper altitudes of that arrangement could then, for example, provide convenient base accommodation and acclimatization for walking, mountaineering and skiing. The sock or tower would be added from the top of the mountain duct up to the 12 to 17 km level.

The heat input and heat flow techniques in the above would be optimised from all considerations such as in the preceding discussions, but with the further effect that the pumping of the hot water up the mountain could be reduced, while retaining the near 300°A limit on temperature, by the use of moist heat. The pumping power could be considerable and would therefore be offset as far as possible by turbines in the return circuit. The pumping power in the total system, also, might be reduced by putting the heat transfer from the water to the air at a lower altitude, perhaps at the valley entrance at below 500 m - but safety and the effect on the environment would need careful study. The use of moist heat might be carried out through the intermediary of filtered sea water, if it were appropriate to increase the nett production of fresh water. The proportion of moist heat adopted could well vary with the season.

Now it would be undesirable to concentrate a high proportion of world resources in any single area. Nevertheless, as an indication of the possibilities of the situation, it would seem that the above arrangement employing rising ducts on a single mountain group representing up to about 2% of the total Himalayan range, together with heat brought from the south, could satisfy the whole of the world demand for power, both now and in the coming say 3 decades. It would be necessary to build up gradually the operating capacity from the pilot scheme value in order to allow the arrangements both for the mountain duct and for the hot water to be integrated with the local community and with visitors as wealth progressively increased. Costs, even at the intermediate scales, according to the writer's very crude analysis seem to show a reasonable possibility of being economic relative to today's costs for electrical generation. However, the acceptability of such schemes generally, and the size of scheme that could be accepted, would be critically dependent on the sensitivity with which the scheme could be integrated into the community and the environment.

Again a variant of the above proposals is possible rather as with the pilot scheme, in that the rising ducts could provide their own heat and could take other heat from the local valleys. The relative simplicity of such arrangements could make them attractive for intermediate levels of power, provided environmental and community requirements could be satisfactorily included.

<u>b.</u> <u>The latent heat of freezing, as a heat source</u>

The schemes discussed so far have mostly used solar heat collectors to provide warm or hot water or air, or have used ocean water. The ocean water tends to have only a small temperature excess over the air to be heated, so that heat transfer presents problems. Also, even hot water used for storage has only a modest useful heat capacity.

A more intense source of heat from water, and one not requiring special heat collectors, is the latent heat of freezing. It would have its own problems for hurricane simulation as the water would need to be pumped to high altitude and say sprayed into the air flow. Liquid water mixed with the frozen would allow some compensating power extraction on the descent. A mountain type of installation with a duct extension to high altitude would allow much or all of the heavy hydraulic and electrical equipment to rest on the local ground.

The arrangement could be used separately from the arrangements previously discussed and, 24 hours of the day, or it could be used in conjunction with the previous arrangements. The Carnot efficiency would be lower than before because of the reduced temperature of input. Some preliminary heat transfer might be arranged for say ocean water if it is initially considerably above freezing.

c. And a different type of proposal

Because of the difficulties of creating an artificial duct to a height of 17 km there are attractions in endeavouring to simulate the natural process by which the hurricane carries its low pressure air to that height. The natural process is by means of the hurricane vortex, as there the radial pressure field from the centrifugal force "holds back" the ambient atmospheric pressure. However, such an arrangement under artificial conditions seems likely to be difficult to achieve, and, even if achievable, seems likely to raise many difficult questions of safety. However, some discussion could be appropriate.

Standard methods of calculation in meteorology give good computer simulation of the strength of hurricane vortices. Also, reasonably simple analytical methods allow approximate calculation of the strength of a natural vortex in terms of the geographical latitude, the radial mass flow of air and the surface friction. Correspondingly, from a very simple, order of magnitude, calculation of an artificial power system vortex, the writer finds that, at say 15° latitude and in otherwise still air, the necessary air flows can be set up if the scale of power is about the same as for the tower unit of section 4, if the ground friction in an annular region of inner diameter about 10 km and equal in area to that of the solar heat collection is about the same as for a reasonably smooth surface at that Reynolds number, and if the ground friction in the region between the diameter of 10 km and the warm core flow could be either eliminated or greatly reduced. In order to eliminate or greatly reduce the friction between the 10 km diameter and the warm core flow a stack of about 3 concentric annular discs of successively smaller outer diameters has the outer part of each disc rotating at about the same speed or a somewhat greater speed than the local nominal vortex. It is then readily shown that, largely because the frictional stress is approximately a function of the square of relative speed, the total frictional dissipation at the stack is very small - in comparison with that in the requisite vortex rotating naturally. The duct containing both the power turbines and the air flow to the core passes under the stack. The total air flow in the vortex and the total power from the core in such an arrangement are each only of the order of one per cent of the values for a hurricane. Consequently, the arrangement could perhaps be made safe.

A feature that would increase the safety would be that the precipitation would centrifuge from the central swirling warm core and induce a cool downdraught in the surrounding vortex. The atmospheric vortex just outside the core would therefore be cool and of low heat content, rather than warm and of high heat content as in a hurricane. Consequently, in the event of an escape of the vortex, the vortex would rapidly dissipate on account of its low temperature and its low heat content, as well as because of its very small scale and the increased friction away from its proper anchorage point.

In a wind, it seems that the force from the wind onto the vortex core could be offset by an angular displacement sideways - as a result of sideways "lift" - and a resulting buoyancy force from the low pressure and slightly warm air in the core.

The above derivation and arguments seemed to fail, provisionally, when calculating the vortex "circulation" in a wind, as it seemed possible to postulate a streamline field in which the circulation was zero when the wind was greater than zero. However, Dr Micky Zdravkovich pointed out in discussion that such a conclusion seemed inconsistent with the existence of natural hurricanes in the presence of even the smallest shear velocity between low and high level winds. Further consideration then indicated that the explanation could lie in the multi-valued nature of the circulation around a body in an airflow. Whereas on a two-dimensional aerofoil in inviscid flow the circulation can take any value, in real flow the trailing edge determines approximately the circulation by the Kutta-Joukowski condition. In the present vortex the circulation may be determined by say the mixing between the core and the external flow, particularly on the pressure side of the vortex, in a manner analogous to that of the "Thwaites flap" or, more remotely, to that of the "Jet Flap". It therefore seemed likely

that non-zero circulation would be possible in the presence of a wind. However, it also seemed that its actual value was likely to be more difficult to predict with a wind than for otherwise still air. There might also be rather rapid changes in circulation with changes in the wind - and that again would raise a question of safety.

However, the overall possibility of using a controlled artificial vortex remains. Orders of magnitude "judgement" indicates that maybe an equivalent 200 km square solar heat receiver could sustain an adequate vortex, with margin, except in high winds. That vortex part of the system might then be of relatively low cost, per unit of output. It might perhaps be run in conjunction with a lake type heat receiver where the water of the lake had a suitable transparent cover to reduce heat loss, effectively like a large solar panel, or the lake liquid consisted, in the known manner, of strong stratified solutions. Such lakes might be created either floating in an ocean or placed in a depression such as that around Lake Chad. In either type of lake the upper or intermediate levels would be used for heat collection; these could then be connected by local ducts to the lower levels, which would act as transport ducts. Diaphragms would separate the lower from the intermediate or upper levels.

Such a total arrangement might then be of very low cost per unit of output. But the problems could be formidable.

Care would be needed in controlling a large source of moist heat of the nature indicated above, in either that or other applications. Escape of the heat could stimulate a large and highly energetic vortex and that in turn could worsen the escape of heat. However, the vortex should dissipate when it moved away from the source of moist heat.

7. Conclusions

i) It might be possible to simulate hurricanes by heating air at ground level and then ducting it to high altitude. The suggested systems would use either solar heat or heat from the ocean, together with either a "self supporting duct" that is based on balloon technology, or a duct running up a mountain, or, in principle, a tower. The mountain duct would probably be extended upwards by a shortened tower or self supporting duct. Certain favourable parts of the world would be chosen for the application if the peoples and governments agree. Moreover, the simulation might be economic for the purposes listed below.

ii) Hurricane simulation could give concentrated and virtually unlimited electrical power by the expansion of the heated air to high altitudes. It could give, in some situations, very large amounts of cold fresh water - from precipitation - for people, animals and irrigation. Moreover, it could provide an artificial cool climate in hot urban regions of the world. Furthermore, when enough suitable simulation schemes have been built, they would be able to prevent hurricanes, by causing the moist heat from which hurricane embryos develop to bypass the altitude range in which the embryos ordinarily do develop. And, enough schemes could probably allow the control of world temperatures, additionally to their influence on the "greenhouse effect", by affecting the amount of cloud cover. In addition, it is possible to argue that enough of the simulation schemes that extract heat from the ocean would, between them, in perhaps a century from now, be able to prevent ice ages.

iii) There appear to be several analogous schemes which could be economic in temperate regions.

iv) Each scheme would need a careful optimisation of the balance between moist and dry heat transfer to the air flow. The concept of dry heat transfer has effectively been taken from the "solar chimney".

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CLAIMS

1. An apparatus for generating an air flow comprising a duct rising to a substantial height and means for providing warm air for passage up the duct, the duct being such that the warm air rises in the duct to a height at which moisture could condense out of the air to cause a further driving force for an air flow through the duct.

2. An apparatus as claimed in claim 1, wherein the duct is a substantially hollow tower.

3. An apparatus as claimed in claim 2, wherein the tower is further provided with internal ducting or fins to cause the air flow to spiral upwards.

4. An apparatus as claimed in claim 1, wherein the duct is in the form of a wind sock.

5. An apparatus as claimed in claim 4, wherein the wind sock is inclined at an angle to the horizontal.

6. An apparatus as claimed in claim 1, wherein the duct may be supported on the side of a mountain.

7. An apparatus for generating an air flow comprising means for generating an air vortex rising to a substantial height and means for providing warm air for passage up the vortex, the vortex extending to such a height that the warm air rises in the duct to a height at which moisture could condense out of the air to cause a further driving force for an air flow through the vortex.

8. An apparatus as claimed in claim 7, wherein the means for generating the vortex comprises rotatable annular discs in conjunction with the warm, rising air flow.

9. An apparatus as claimed in any preceding claim, wherein the means for providing warm air for passage up the duct or vortex comprises a flat transparent roof surrounding or close to the duct or vortex to heat the air beneath the roof by solar radiation.

10. An apparatus as claimed in any of claims 1 to 8, wherein the means for providing warm air for passage up the duct or vortex comprises a heat exchanger.

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Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASE: WPI

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Documents considered relevant following a search in respect of claims 1-10

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 2081390 A (CENTRELES ENERGETICS) = US 4452046 see figures 2 and 5, line 121, page 1 - 147, page 3	1,2,3,7, 9
X	US 4878349 A (CZAJA) see figure and line 1 column 1 to line 51, column 2	1,2,7
X	US 4359870 A (HOLTON) whole document	1,6,7,9
X	FR 002442354 A1 (ROUSTAND) see figure 1 and condensation collection slots 6,7,8; solar acceleration 17	1,2,9
X	FR 002307982 A2 (GRANATA) see figures	

Category	Identity of document and relevant passages	Relevant to claim(s)

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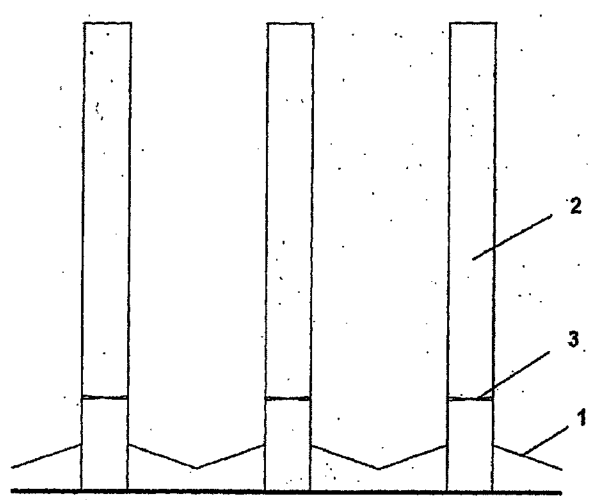
Die folgenden Angaben sind den vom Anmelder eingereichten Unterlagen entnommen

(54) Aufwindkraftwerk

(57) Die Erfindung betrifft ein Aufwindkraftwerk in an sich grundsätzlich bekannter Ausführung, dass sich durch vergleichsweise kostengünstigen Aufbau auszeichnet. Aufgabe der Erfindung ist es, den Nachteil des Standes der Technik nachhaltig zu minimieren, so dass es sich lohnt, angesichts der Förderung erneuerbarer Energie mit Aufwindkraftwerken Strom zu produzieren. Es soll insbesondere eine Lösung angegeben werden, die den Aufwand für den Bau des Kamins solcher Kraftwerke drastisch reduziert. Erfindungsgemäß ist vorgesehen, Industrieschornsteine großer Höhe, sowohl stillgelegte als auch im Betrieb befindliche, als Kamin für Aufwindkraftwerke zu verwenden. Dabei ist es nach Maßgabe der Erfindung vorteilhaft, zusätzlich die aus Industrieabgasen bzw. bislang in Kraftwerksprozessen nicht mehr verwendbare Restenergiepotentiale zu nutzen.



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Beschreibung

[0001] Die Erfindung betrifft ein Aufwindkraftwerk in an sich grundsätzlich bekannter Strukturierung, das sich durch vergleichsweise einfachen und kostengünstigen Aufbau auszeichnet; seine Anwendung ist – im Gegensatz zu realisierten und geplanten Pilotanlagen – in jeder Hemisphäre vorteilhaft möglich.

[0002] Bekanntlich handelt es sich bei Aufwindkraftwerken um spezielle Solarkraftwerke, nämlich um solche, die unter Ausnutzung des Kamineffektes eine Luftströmung über eine Windturbine zur Energieerzeugung führen. Unter einem riesigen Glas- oder durchscheinenden Plastikdach, dem so genannten Kollektor, wird die Luft durch Sonneneinstrahlung erwärmt und – durch die Formgebung des vorzugsweise Glasdaches unterstützt – einem Kamin, der in der Mitte des Kollektors steht, zugeführt, in dem sie nach oben strebt. Von den Rändern des Glasdaches strömt die kühlere Umgebungsluft nach, die sich dann gleichfalls erwärmt. Eine im Kamin eingebaute Turbine wandelt die so erzeugte Windenergie mit Hilfe eines Generators in elektrische Energie um.

[0003] Aufwindkraftwerke stellen also einen Sonderfall der Nutzung von Solarwärme dar. Zu ihren Vorteilen zählt im Vergleich zu den konzentrierten Systemen der Solartechnik die Möglichkeit der Nutzung der diffusen Strahlung und die Verlängerung der Nutzungsdauer über Wärmespeicher, die einen Teil der tagsüber eingestrahlten Energie nachts als Wärme freisetzen können. Hierzu ist die Verwendung dunkler, wasserführender Röhren, die den Erdboden unter dem Kollektor bedecken, vorgesehen.

[0004] Die ersten Überlegungen zu Aufwindkraftwerken stammen bereits aus den 30iger Jahren des 20. Jahrhunderts; aber erst Mitte **1986** konnte in Manzanares, Spanien eine von J. Schlaich, Deutschland, konstruierte Pilotanlage, die bis Anfang **1989** fast ohne Unterbrechung mit einer Spitzenleistung von 50 kW lief, in Betrieb genommen werden. Der Kollektor dieser Anlage hatte einen Durchmesser von 240 m; der des 195 m hohen Kamins aus Blech, der 1989 von einem Orkan zu Fall gebracht wurde, betrug 10 m.

[0005] Im Ergebnis des Pilotbetriebes wurde immer wieder angegeben, dass wirtschaftlich arbeitende Anlagen wesentlich größer sein müssten. So sollte der Kamin einer (nicht realisierten) 100 MW-Anlage in Gahna eine Höhe von 950 m bei einem Durchmesser von 115 m aufweisen; der Kollektor hätte hierbei eine Fläche von mehreren Quadratkilometern beansprucht (vgl. www.energieinfo.de). Noch größere Ausmaße (und damit Aufwendungen) soll ein Kraftwerk, welches in Australien entstehen soll, aufweisen. Dieses Projekt rechnet mit einem 1000 m hohen und 130 m dicken Kamin und einer Glasfläche von 10 km Durchmesser (vgl. SPIEGELONLINE **2002**).

[0006] Es liegt auf der Hand, dass für solche Dimensionen eines Aufwindkraftwerkes in Europa kein Raum ist, so dass als Standorte nur entlegene Gebiete wie z. B. Wüsten oder Wüstenränder in Betracht kommen. Aber auch dort, wo Platz und Sonnenlicht im Überfluss vorhanden sind, sind die außerordentlich hohen Baukosten ein kaum überwindbares Hindernis. Namentlich sind deshalb Projekte in Afrika und Asien (u. a. Gahna, Sudan; Indien) gescheitert; auch für Australien muss an die Machbarkeit eines solchen gigantischen Vorhabens unter den Aspekten Infrastruktur, Dauer und Risiken der Genehmigungsverfahren und Höhe der notwendigen Anfangsinvestitionen und daraus folgend Wirtschaftlichkeit erheblicher Zweifel gerichtet sein.

[0007] Zudem sind eine Reihe von Vorschlägen bekannt, die auf eine Anwendung des Prinzips eines Aufwindkraftwerkes im dicht besiedelten und vergleichsweise Sonnenarmen Europa zielen. Dabei stehen neben zahlreichen Detail- (u. a. DE 41 14 501) und einfallsreichen steuerungstechnischen Lösungen, wie z. B. die Ausbildung eines Rundum-Kanals für die Luftströmung am Tage und eines solchen Kanals für die Luftströmung bei Nacht (DE 297 15 254), Vorschläge, die die geographischen Nachteile des Standortes ausgleichen sollen, im Zentrum der Entwicklungen. So wird in DE 199 39 663 ein alternatives System zur bivalenten Stromerzeugung aus Wind- und Verbrennungsenergie vorgeschlagen; gemäß DE 298 24 124 soll ein Aufwindkraftwerk mehrere Arten von industrieller Abwärme nutzen und schließlich wird angeregt, die Solarenergie gezielt wärmespeichernden Steinflächen (DE 299 17 453) oder sonstigen Wärmespeicherelementen (DE 100 23 424) zuzuführen, um den Wirkungsgrad eines Aufwindkraftwerkes zu erhöhen. Andere Entwicklungen wollen die Beschränkungen bezüglich der Höhe von thermosolaren Aufwindkraftwerken dadurch aufheben, dass sie keinen vertikalen, sondern einen entlang einer Anhöhe geneigten Kamin verwenden (DE 198 06 489, DE 195 43 514, die Anlehnung eines Kollektors an einen Berg ist auch aus DE 198 06 144 bekannt, die einer diesbezüglichen Luftführungsanordnung aus DE 198 44 659).

[0008] Des Weiteren sind vielfältige Bemühungen bekannt, die hohen Baukosten von Aufwindkraftwerken, besonders die für die Errichtung des Kamins, zu minimieren. Hierfür wird beispielsweise in DE 40 00 100 der Kamin als Kaminturm mit einem trichterförmigen ausladenden Fuß ausgeprägt. Der Fuß besitzt über seinem gesamten Außenumfang verteilt Lufteintrittsöffnungen und weist einen mindestens doppelt so großen Außendurchmesser wie der Kaminturm auf. Dadurch soll eine solche Anlage zur Nutzung der Sonnenenergie technisch einfacher aufbaubar und kostengünstiger sein.

[0009] Weiterhin liegen Vorschläge vor, den Kamin als Schlauch aus Plaste auszubilden, so z. B. mittels Schlauchfolie, die durch feste oder aufblasbare ringartige Kammern zu einem so genannten Saugschlauch versteift wird. Nach DE 100 46 287 soll der Kamin eine flexibelwandige gasundurchlässige Ummantelung aufweisen, die in Verbindung mit mindestens einem mit Traggas gefüllten Hohlkörpergebilde steht, das den Kamin selbsttragend aufrecht hält. Schließlich wurde angeregt, dass ein konischer, nach oben auseinander gehender Kaminschlauch aus hochfestem Gewebematerial oder hochfesten Kunststofffolien den Aufwindkanal bildet und dass an dem Kaminschlauch in Abständen heliumgefüllte Ballonringe oder Schläuche zum Tragen des Kaminschlauches angeordnet sind.

[0010] Aber auch diese Entwicklungen haben wie die vorgenannten bislang zu keiner kommerziellen Nutzung des Prinzips eines Aufwindkraftwerkes geführt. Nach wie vor stehen dem die hohen Anfangsinvestitionen und daraus folgend die Höhe der Zinsen, die in erster Linie den Preis des mit dieser Technik erzeugten Stromes bestimmen, entgegen.

[0011] Aufgabe der Erfindung ist es, den Nachteil des Standes der Technik nachhaltig zu minimieren, so dass es sich lohnt, angesichts der Förderung erneuerbarer Energie mit Aufwindkraftwerken Strom zu produzieren. Es soll insbesondere eine Lösung angegeben werden, die es ermöglicht, den Aufwand für den Kamin drastisch zu reduzieren.

[0012] Diese Aufgabe wird durch die Merkmale des Anspruches 1 gelöst. Zweckmäßige Ausgestaltungen der Erfindung ergeben sich aus den Merkmalen der Ansprüche 2 bis 8.

[0013] Nach Maßgabe der Erfindung ist vorgesehen, Industrieschornsteine großer Höhe als Kamin für Aufwindkraftwerke zu verwenden. Hierfür sind sowohl stillgelegte als auch im Betrieb befindliche Schornsteine vorgesehen. Das

Kraftwerk ist hierbei in grundsätzlich bekannter Weise strukturiert und besteht im wesentlichen aus einem Kollektor, vorzugsweise einem vom Erdboden beabstandeten Glasdach, und einem Kamin mit wenigstens einer Turbine, die von der im Kamin unter adiabatischen Expansion aufsteigender Luft, die vorher durch die solare Einstrahlung erwärmt wurde, angetrieben wird. Das Wesen der Erfindung schließt ein, dass auch mehrere Schornsteine, die räumlich in geeigneter Weise zueinander stehen, genutzt werden, die jeweils von dem Kollektor umschlossen sind, oder an denen separat der Kollektor oder ggf. Kollektorsegmente angeschlossen sind. Vorzugsweise sind mindestens 250 m hohe Schornsteine verwendet.

[0014] Zudem ist es vorteilhaft, bei noch im Betrieb befindlichen Schornsteinen neben der Energie, die durch die aufsteigende, vom Kollektor erwärmte Luft erzeugt wird, die Restenergiepotentiale von Industrieabgasen zum Antrieb der Windturbine zu nutzen. Des Weiteren wird vorgeschlagen, analog die Abwärme aus Kraftwerksprozessen und/oder Kühltürmen zur Verbesserung der Gesamtbilanz des Kraftwerkes der Windturbine zuzuführen, die in bekannter Weise auch mehrfach in einer oder mehreren Ebenen in dem Schornstein angeordnet sein kann.

[0015] Die Kopplung der Nutzung des Aufwindpotentials von Industrieabgasen und/oder der durch konventionelle Kraftwerkprozesse sonst nicht mehr (infolge des geringen Temperaturunterschiedes zur Umgebungstemperatur) technisch sinnvoll nutzbaren Energie mit einem Aufwindkraftwerk eröffnen gerade diese Möglichkeit. Der daraus resultierende Beitrag zum Ressourcen- und Umweltschutz ist offensichtlich.

[0016] Der Vorschlag, stillgelegte Industrieschornsteine als Kamin eines Aufwindkraftwerkes zu verwenden, spart die hohen Kosten, für deren ansonsten notwendigen Abriss.

[0017] Die Aufwendungen für die Anpassung der Schornsteine (egal, ob stillgelegt oder in Betrieb befindlich) an die jeweils konkrete Ausgestaltung eines damit bewerkstelligten Windkraftwerkes sind selbstredend gegenüber eines vergleichbaren Neubau eines Kamins praktisch fast vernachlässigbar.

[0018] Die Erfindung wird nachfolgend anhand zweier Ausführungsbeispiele näher erläutert.

[0019] **Fig.** 1 zeigt hierfür in schematischer Weise die Verwendung stillgelegter Industrieschornsteine als Kamin eines Aufwindkraftwerkes. Die drei (ehemaligen Kraftwerks-)Schornsteine **2** sind jeweils 300 m hoch und in einem Kollektor, ausgeführt als vom Boden beabstandetes Glasdach **1**, integriert. In jedem Schornstein **2** ist in grundsätzlich bekannter Weise eine Windturbine **3** eingebaut.

[0020] **Fig.** 2 verdeutlicht in oben beschriebener Weise die Verwendung eines in Betrieb befindlichen Industrieschornsteines einschließlich der Nutzung der Abwärme aus einem Kraftwerksprozess. Dargestellt ist der Schornstein **2**, an dem ein Tunnel oder eine Röhre angeschlossen ist, in dem bzw. in der sich die Windturbine **3** und der Wärmeübertrager **4**, der durch die Leitung **5** mit dem Kraftwerksprozess verbunden ist, befinden. Der Tunnel oder die Röhre trägt den als Glasdach **1** ausgeführten Kollektor.

[0021] Beide Ausführungsvarianten können unter den jeweiligen Glasdächern **1** hier nicht dargestellte Wärmespeicher aufweisen.

Patentansprüche

1. Aufwindkraftwerk zur Gewinnung von Elektroenergie aus einem insbesondere durch solare Einstrahlung erzeugten Warmluftstroms, im Wesentlichen bestehend aus einem Kollektor zur Erzeugung der Warmluft und einem Kamin, in dem sich mindestens eine Turbine befindet, die durch die im Kamin unter adiabatischer Expansion aufsteigenden Luft angetrieben wird, **dadurch gekennzeichnet**, dass es als Kamin Schornsteine **(2)** verwendet.

2. Aufwindkraftwerk nach Anspruch 1, dadurch gekennzeichnet, dass mehrere Industrieschornsteine **(2)**, die räumlich in geeigneter Weise zueinander stehen, genutzt werden, wobei diese von einem Kollektor, vorzugsweise aus Glas bestehend, umschlossen oder an denen Kollektorsegmente in Form von Glasdächern **(1)** angeschlossen sind.

3. Aufwindkraftwerk nach Anspruch 1 und 2, dadurch gekennzeichnet, dass die Industrieschornsteine **(2)** mindestens 250 m hoch sind.

4. Aufwindkraftwerk nach Anspruch 1 bis 3, dadurch gekennzeichnet, dass als Kamin stillgelegte Industrieschornsteine **(2)** verwendet sind.

5. Aufwindkraftwerk nach Anspruch 1 bis 3, dadurch gekennzeichnet, dass als Kamin im Betrieb befindliche Schornsteine **(2)** verwendet sind, so dass neben der durch Solarenergie erwärmten aufsteigenden Luft die Restenergiepotentiale von Industrieabgasen zum Antrieb der Windturbine **(3)** genutzt wird.

6. Aufwindkraftwerk nach Anspruch 1 bis 5, dadurch gekennzeichnet, dass einem oder mehreren Industrieschornsteinen **(2)** Abwärme aus Kraftwerksprozessen, namentlich von Kühltürmen, zugeführt wird.

7. Aufwindkraftwerk nach Anspruch 1 bis 6, dadurch gekennzeichnet, dass an den Industrieschornsteinen **(2)** ein horizontal ausgeführter Tunnel bzw. eine horizontal angeordnete Röhre, in dem bzw. in der sich Wärmeübertrager **(4)** befinden, wobei der Tunnel bzw. die Röhre den als Glasdach ausgeführten Kollektor tragen, angeschlossen ist.

8. Aufwindkraftwerk nach Anspruch 1 bis 7, dadurch gekennzeichnet, dass die Glasdächer **(1)** alle als Kamin dienende Industrieschornsteine **(2)** umschließen bzw. an denen segmentartig angeschlossen sind.

Hierzu 2 Seite(n) Zeichnungen

- Leerseite -

ZEICHNUNGEN SEITE 1

Nummer: DE 102 24 849 A1
Int. Cl.[7]: F 03 D 9/00
Offenlegungstag: 24. Dezember 2003

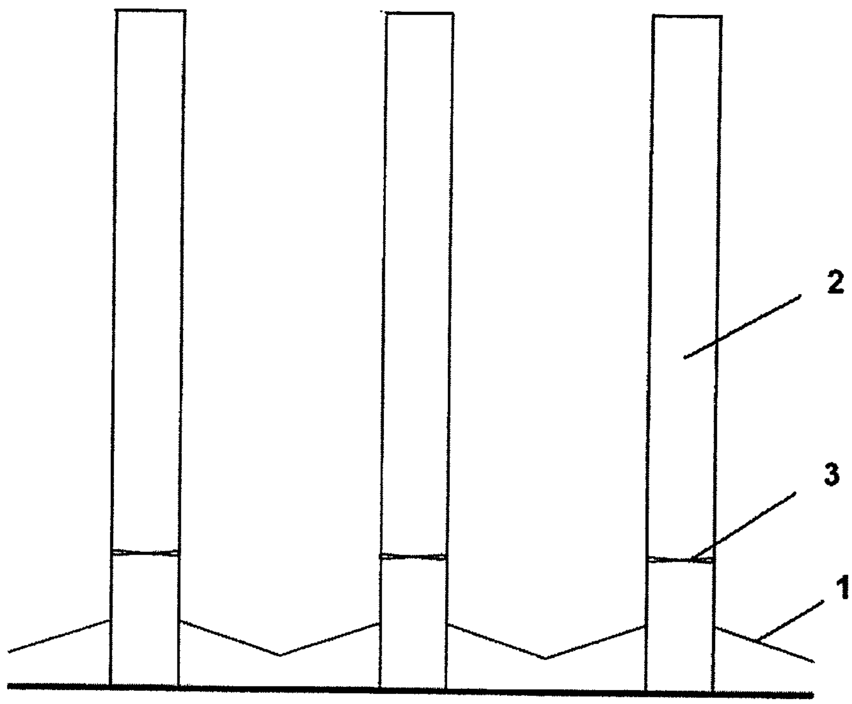

Fig. 1

ZEICHNUNGEN SEITE 2

Nummer: **DE 102 24 849 A1**
Int. Cl.[7]: **F 03 D 9/00**
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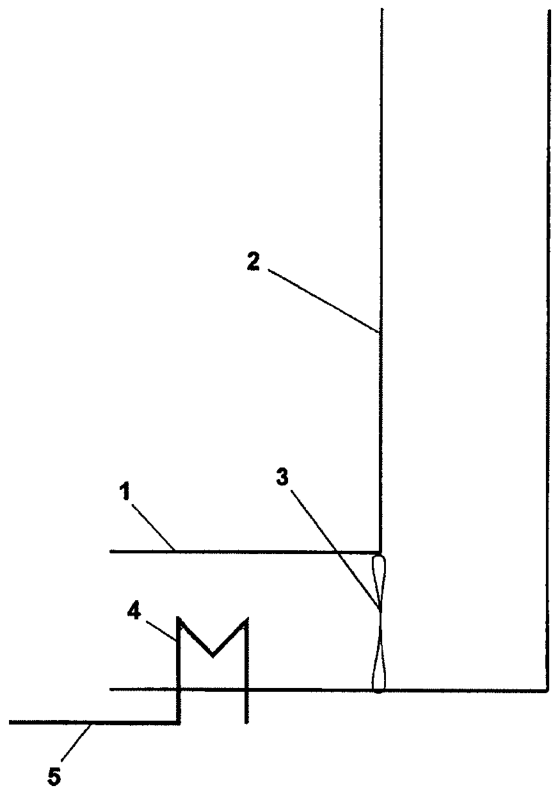

Fig. 2

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A1

DEMANDE DE BREVET D'INVENTION

(21) N° 75 12123

(54) **Générateur électrique à énergie solaire et turbine à air.**

(51) Classification internationale (Int. Cl.^{2}). **F 03 G 7/02; F 03 D 9/00; H 02 K X.**

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(71) Déposant : **GRANATA François, résidant en France.**

(72) Invention de :

(73) Titulaire : *Idem* (71)

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L'invention est relative à un générateur électrique utilisant simultanément l'énergie solaire et l'énergie éolienne, avec régulation énergétique. Des éoliennes classiques sont bien connues, mais ne fonctionnent que lorsque les vents ont une force suffisante. On sait que les vents sont provoqués par l'énergie solaire créant des différences de température et donc des dépressions. L'idée de base qui a donné naissance à l'invention a consisté à créer un vent artificiel provoqué par la captation de l'énergie solaire qui rayonne le jour au moins sous la forme d'infra-rouges diffusés par les nuages. Ce vent artificiel se combine au vent naturel éventuel capté aussi par l'installation, et l'ensemble actionne un générateur électrique par l'intermédiaire d'une turbine. Des moyens divers sont alors combinés pour accumuler cette énergie et la réguler pour sa distribution.

Selon l'invention, l'ensemble technique de récupération d'énergie solaire est caractérisé par une verrière de forme sensiblement conique, raccordé à une cheminée centrale entourant une turbine à axe vertical, ladite verrière couvrant des dalles et une piscine annulaires dont les parois sont noircies, laissant une entrée d'air annulaire au-dessus desdites dalles, ladite turbine commandant une dynamo par l'intermédiaire d'un embrayage automatique, des moyens d'accumulation de l'énergie électrique produite par le groupe turbo-dynamo.

L'invention sera mieux comprise à l'aide de la description suivante et du dessin annexé.

La figure unique représente en coupe verticale l'ensemble de l'installation partiellement enterrée.

On voit en 1 le niveau du sol, en 2 une piscine annulaire de 100 m^3, emmagasinant les calories le jour. Cette piscine est recouverte d'une feuille de plastique transparente s'opposant à l'évaporation. Elle est entourée d'une dalle annulaire en béton 4 peinte en noir ainsi que le fond et les parois de la piscine, en vue d'accumuler de la chaleur pendant le jour.

L'ensemble est recouvert d'une verrière 5 en forme de ruche, formée de 3 zones en troncs de cônes, de pente plus faible vers la périphérie.

Entre la dalle de béton et la verrière est ménagée une entrée d'air périphérique de 16 m^2, grillagée 6.

La verrière se raccorde dans sa partie supérieure avec une cheminée , surface de révolution 7 de profil curviligne pré-

sentant un diamètre minimum dans la région 8 et un évasement progressif jusqu'à sa partie haute en 9. L'ensemble de la surface est réalisé en polyester armé. L'orifice supérieur est recouvert par un déflecteur curviligne 10 coiffé d'un chapeau conique de protection 11. Entre l'évasement 9 et le déflecteur se présente une sortie d'air circulaire 12 en nappe centrifuge sensiblement horizontale.

Dans la zone 8 de la cheminée se trouve une turbine 13 à axe vertical. Un embrayage automatique 14 est apte à la relier à une dynamo 15.

Le volume d'air sous la verrière en 16 est de 380 m^3. Il subit un effet de serre, se dilate et s'allège, et se trouve accéléré par effet venturi à travers l'orifice de la cheminée qui a 0,60 m^2 de surface dans sa partie la plus réduite. Le courant produit par la dynamo est régulé et orienté préférentiellement vers le réseau. Une certaine valeur, variable selon la demande, est dérivée sur un moteur 17 qui entraîne, grâce à une boîte automatique 18, un volant inertiel en béton 19 de 13 tonnes. Ce volant est ensuite maintenu à une vitesse de 10.000 t/m par de brèves impulsions.

Lorsque le volant a sa pleine vitesse, le courant qui servait à son mouvement sert, alors, à séparer l'hydrogène de l'eau d'une piscine spéciale 20 aménagée à l'intérieur du cône central. Le niveau y est maintenu constant par une vanne automatique 21 d'un type connu.

L'hydrogène séparé par électrolyse conduit par une tuyauterie 26 est stocké dans un ballon 22, dont l'expansion est limitée par un container 23 de 2 m^3. Une tuyauterie 24 menant à un robinet extérieur 25 permet la récupération de l'hydrogène du ballon. L'oxygène sous-produit de la séparation pourrait être récupéré, mais par mesure de sécurité, il est évacué directement dans le flux d'air par l'orifice 27.

Pendant la journée, la verrière laisse passer les infra-rouges solaires, le béton s'échauffe et échauffe les 380 m^3 d'air sous verrière.

Dans la première partie de la nuit, c'est l'eau de la piscine qui va restituer l'énergie calorifique emmagasinée le jour, la convexion continue jusqu'à ce que l'eau redevienne à la température ambiante. Dès que la convexion cesse, la turbine se débraye et la dynamo cesse de débiter du courant. Le volant iner-

tiel restitue alors l'énergie cinétique emmagasinée par son moteur qui tourne maintenant en dynamo.

Plusieurs variantes sont possibles, selon le principe de l'invention dont on a donné un exemple de réalisation. Une version simplifiée, plus économique, peut donc être réalisée en supprimant le volant inertiel et son moteur et boîte de vitesse. L'ensemble peut aussi être remplacé par une batterie d'accumulateurs. Le principe reste fonctionnel tant que dure la conversion, soit toute la journée et une partie de la nuit. Les accumulateurs prennent ensuite la relève.

REVENDICATIONS

1. Ensemble technique de récupération d'énergie solaire, caractérisé par une verrière de forme sensiblement conique, raccordée à une cheminée centrale entourant une turbine à axe vertical, ladite verrière couvrant des dalles et une piscine annulaires dont les parois sont noircies, laissant une entrée d'air annulaire au-dessus desdites dalles, ladite turbine commandant une dynamo par l'intermédiaire d'un embrayage automatique, des moyens d'accumulation de l'énergie électrique produite par le groupe turbo-dynamo.

2. Installation selon la revendication 1, caractérisée par une deuxième piscine annulaire au centre de la première, des moyens d'électrolyse permettant la récupération de l'hydrogène dans un ballon expansible enfermé dans un container limitant ladite expansion.

3. Installation selon la revendication 1, caractérisée en ce que les moyens d'accumulation de l'énergie comprennent un volant inertiel à axe vertical, mis en action par un moteur-dynamo et une boîte de vitesse automatique.

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